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Switch to NE Alloy Steels

to Save Critical Metals



TO HELP conserve nickel, chromium, vanadium and other scarce metals, the War Production Board's ablest metallurgists have developed NE (National Emergency) Alloy Steels. These new steels contain relatively small quantities of alloying elements in such combination as to produce physical properties usually attributed to steels of much higher

alloy content. The War Production Board stipulates the use of the new NE Alloys to replace the standard SAE and AISI Alloy Steels for a wide range of applications.

Ryerson NE Alloy Steel stocks in six specifications, all fine grain, will be available shortly; and will consist of sizes ranging from ½-inch to 7-inch rounds, in three groups:

Carburizing Grades

NE 4023 and NE 8620.

To Replace AISI and SAE

Nos. A 2300, A 2500, A 3100,
A 4100, A 4600, A 5100, A 6100.

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NE 4042 and NE 8744.

To Replace AISI and SAE

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Only limited data on heat-treatment response or physical properties will be available when NE Alloys are first ready for shipment. The WPB is anxious to know how these new steels will function and requests all NE Alloy users to report results in working with these new steels. Ryerson will cooperate fully with

users, supplying laboratory test data, and all other available information.

• • •

If you now use Alloy steel, let Ryerson help you in adapting NE Alloys to your requirements wherever possible. Write, wire or phone the nearest of the ten Ryerson plants.

JOSEPH T. RYERSON & SON, Inc., Chicago, Milwaukee, St. Louis,
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RYERSON STEEL-SERVICE

ALUMINA FROM LOW GRADE BAUXITE, ALUNITE AND CLAY

By Advisory Committee to WPB*
on Metals and Minerals
of the National Academy of Sciences

ABOUT TWO POUNDS of alumina (aluminum oxide, Al_2O_3) of high purity are required for the production of each pound of metallic aluminum. Projected production of metallic aluminum in the United States is now seven to ten times the peacetime rate a few years ago. This great expansion was started for purposes of defense and was augmented for the prosecution of the war.

In the past, all the alumina for the production of aluminum in the United States has been obtained from bauxite. Part of the bauxite was mined in the United States—chiefly in Arkansas—and part was imported from Dutch Guiana. All of it was chemically treated in the United States to separate the greater part of the aluminum oxide from the bauxite. The chemical treatment was effected by alkaline solutions by a method known as the Bayer process. The ingredients of the bauxite other than alumina, such as the compounds of iron, titanium and silicon, constitute the tailings from the Bayer process; it contains sufficient iron to give it a red color and hence it is called "red mud". Lime and soda, used in the processing, are also present. Varying amounts of alumina remain in the red mud, depending upon the characteristics of the bauxite, the effectiveness of the treatment and, in particular, upon the amount of silica originally present in the bauxite. High-silica

bauxites result in high alumina loss in the red mud tailing.

Because of this relationship between the silica content of the bauxite and the alumina lost in the Bayer process treatment, there has been an incentive in the past to use low-silica bauxites. Much of the Dutch Guiana bauxite is low in silica and hence is a splendid Bayer process feed. In the domestic bauxites the silica content varies all the way from less than 5% to up to 25 or 30%. Bauxites having a low silica content have been mined here for more than 40 years to provide alumina for the production of aluminum and for other purposes. While some of the higher silica bauxite has been mined for chemical purposes, most of it remains in the ground. Although there is no sharp dividing line between low-silica and high-silica bauxite, a few years ago an upper limit of about 5% silica was used to distinguish Bayer process bauxite from high-silica bauxite. In recent years, however, material containing more than 7% silica has been used as Bayer process feed.

Alumina is now produced in three plants, one in Illinois and two in Alabama, and their

*This committee has been studying, for more than a year, various methods of making alumina for the production of aluminum. Several clay processes have been given careful consideration. The War Production Board has asked for recommendations, on the basis of these studies, for the production of alumina from domestic raw materials and, in particular, to outline practical procedures for the production of alumina from clay. The Alumina Subcommittee, FRANCIS C. FRARY, OLIVER C. RALSTON, ROBERT S. SHERWIN and JOHN D. SULLIVAN, has considered this matter at length, and this report, dated June 1, 1942, reflects their conclusions.

effective operation depends on a supply of low-silica bauxite, a substantial part of which is now being imported from Dutch Guiana and must be transported by ship—a hazardous operation. There being no known available deposits of bauxite in Canada, Mexico or other accessible foreign countries, it seems advisable to consider the steps necessary for the production of our entire alumina requirements from domestic raw materials. It may also be necessary to export some alumina to Canada.

High-Silica Bauxite

Next to low-silica bauxite, the best raw material for the production of alumina is high-silica bauxite. Two commercial possibilities now exist:

1. Certain high-silica bauxites can be treated by a washing process with a recovery of 60 to 80% of the original feed in the form of low-silica bauxite. The washed bauxite is then treated by the Bayer process.

2. High-silica bauxites can be treated by the Bayer process at an additional cost for chemicals and freight and at an additional cost of processing as a result of lower yields.

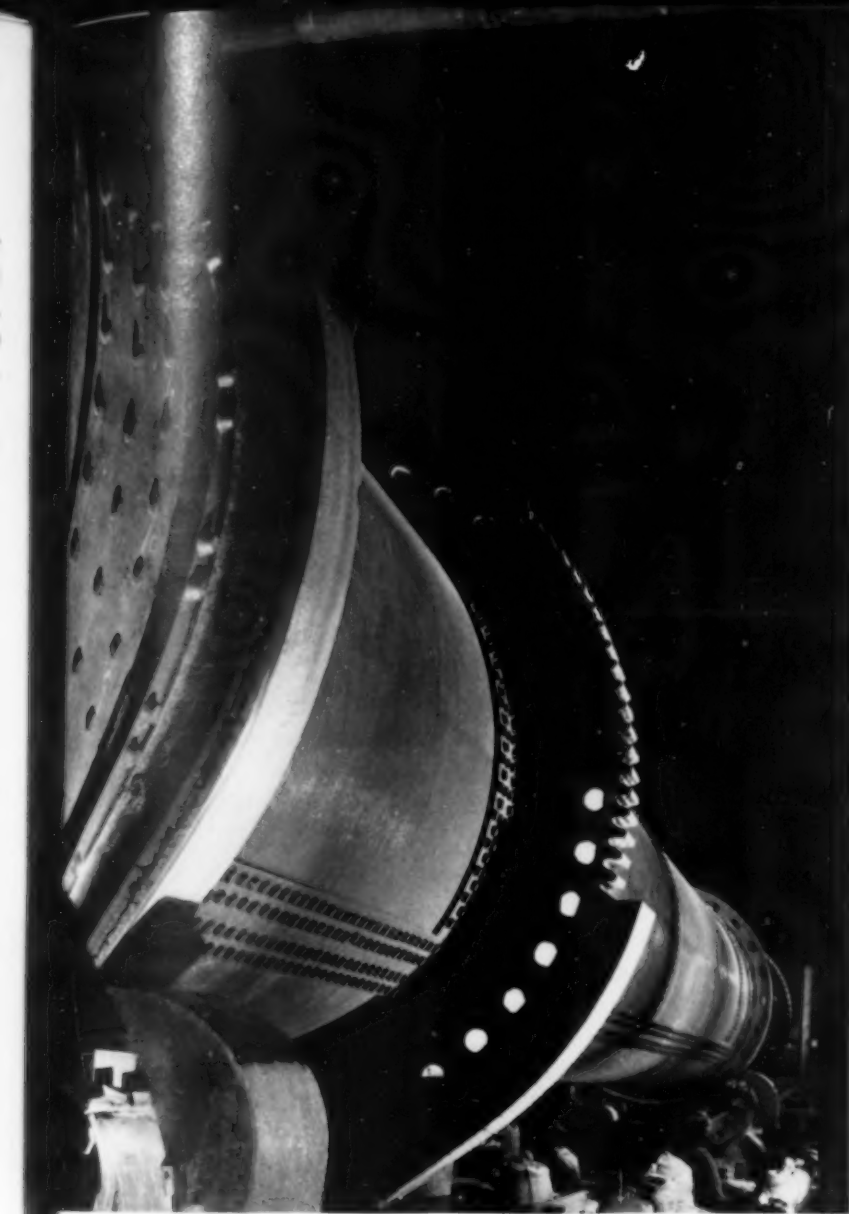
There is a third possibility of beneficiating high-silica bauxite by flotation or other methods. It was referred to a special subcommittee and the studies did not seem to be very promising.

A fourth plan is a lime-soda sintering process, now being put into partial operation at the alumina works of the Defense Plant Corp., where it is now planned first to put all the bauxite directly through the Bayer plant, run entirely on high-silica bauxite (average silica content estimated to be about 13%). About 70% of the contained alumina will thus be removed directly. The tailings, or red mud, will then be subjected to the lime-soda sintering operation; it will itself contain some soda. It will contain practically all the silica of the original bauxite and a considerable amount of alumina. Lime will be added in the form of pulverized limestone and sufficient soda will be added to bring the mixture to the proper composition for sintering. The sintered product will then be leached and the liquors will be added to the Bayer process liquors. The tailings from this operation will contain very little alumina. Recovery of alumina from a ton of high-silica bauxite in this plant should be comparable to the recovery from a ton of low-silica bauxite when treated by the Bayer process alone.

In a previous report we estimated the reserves of low-silica bauxites in the United States to be on the order of 10 million tons*, and of high-silica bauxites on the order of 30 million tons. On first thought, it might be considered a matter of simple arithmetic to show that there is little need to consider anything but the high-silica and low-silica bauxites for the production of aluminum for the present war. Assuming that the projected expansion program for the production of alumina is realized as early as the end of 1943, some 6,000,000 tons of bauxite annually would appear to be sufficient not only for all domestic uses, but also for some exportation to Canada. By the use of arithmetic, it would then be indicated that we could run for 20 months on low-silica bauxite and then continue for another five years on high-silica bauxite. The problem, however, is not so simple as this. To mine all the known bauxite would require vast overburden stripping and many underground mining developments. Furthermore, much of the low-silica bauxite is intermingled with high-silica bauxite. This is a problem that must be studied in detail by experts in order to appraise the various factors.

There can be little doubt, however, about the advantage of operating a plant without the need of separating ore pockets of low-silica bauxite from the high-silica bauxite. For the most effective use of domestic raw materials, therefore, it would seem desirable to consider having lime-soda sintering plants constructed at each of the Bayer process plants. In addition to the current production of red mud, there are millions of tons of it which has accumulated during the past 30 years. The amount of alumina in this tailings pile is equivalent to that contained in about one million tons of bauxite. The alumina in it is higher in proportion to the silica than in kaolin clay; lime and soda are also present. To prepare this red mud for the lime-soda sintering operation would require less added lime and soda per pound of alumina than in the treatment of kaolin clay. It is already mined and pulverized. The new soda consumption would also be reduced as a result of the soda recovery from the red mud.

*EDITOR'S NOTE — Judge CAFFEY's recent judgment in the Anti-Trust action against Aluminum Co. of America cites testimony of G. C. BRANNER, State Geologist of Arkansas, who listed the State's resources as of May 1, 1940, at 10,300,000 tons of aluminum grade bauxite (55% Al_2O_3 and 7% max. SiO_2) as proven by core drills and test pits, plus "potential ore" of somewhere between 10 and 20 million tons.



Rotary Kilns, Similar to Those for Burning Cement, for Dehydrating Purified Aluminum Trihydrate. Photo by Aluminum Co. of America

It is therefore suggested that immediate study be given to the plan of constructing lime-soda sintering departments at all of the American alumina plants, not only to improve alumina recoveries by producing a low alumina tailing, but also to enable them to treat high-silica bauxite and the present store of old red mud.

Alumina from Clay

It should be pointed out that high-silica bauxite is, in effect, a mixture of bauxite and clay. Therefore, inasmuch as the Defense Plant Corp.'s alumina plant will recover most of the alumina from the clay in the high-silica bauxites, it may be said that substantial amounts of alumina will actually be produced from clay in this plant.

For the purposes of this discussion, the red mud from the Bayer operation in a plant treating high-silica bauxite may be considered as clay. If no red mud were available a certain

amount of clay could be treated by the lime-soda process and the liquors could be added to the Bayer process liquors and thus, literally, alumina would be produced from clay. How much clay could be used in proportion to the original bauxite is not now known, but laboratory tests indicate that the amount should be substantial, and it will be desirable to find out the maximum amount of red mud, clay, or red mud-plus-clay that can actually be utilized commercially in this combination Bayer-lime-soda process.

If all the American alumina plants are equipped to operate on high-silica bauxite they are, at the same time, equipped to utilize a substantial amount of clay for the production of alumina. Such a program would appear to offer the best means of conserving domestic bauxite and at the same time offer the best means of utilizing existing alumina equipment in the manufacture of alumina from clay. It should be made clear that the changing of a Bayer plant to a combination Bayer-lime-soda plant involves much more than the mere addition of a set of kilns. The use

of high-silica bauxite will result in an increased amount of red mud, and the lower lime content may increase filtering difficulties. Among other things, additional mud-handling equipment will be needed, and means must be provided for controlling the moisture content of the mud, mixing of lime and soda, proportioning the kiln feed, and controlling the liquors. Although the conversion of a Bayer plant involves somewhat of a major operation, no other program seems to offer as much promise.

From the information now available, it would appear that the lime-soda sintering process can be used effectively on kaolin only in conjunction with a Bayer plant. There should be one or more processes ready for operation for the production of alumina from clay in which there is no dependence on a Bayer plant. The Committee believes that a modified Pederesen process offers the greatest promise. In skeleton form, this process consists of sintering the clay with lime and subsequently leaching

with soda. There are many variations to be studied, not only in the sintering and leaching, but in the treatment of the liquors as well. Results of many laboratory experiments, here and abroad, give promise that the process will be operable, but it will be desirable to carry out additional work on a test plant basis to obtain data for the construction of a production unit. It is therefore recommended that the War Production Board allocate \$100,000 to the War Metallurgy Committee for such a pilot plant and its operation, and also assist in the procurement of equipment. If the results are as expected it will be possible in the future to produce, from clay, alumina of a suitable grade for the manufacture of aluminum, without the use of acids. An acid-free process is a goal much to be desired.

The Eastern Experiment Station of the Bureau of Mines at College Park is also working on the lime-soda sintering of clay, and this work should be continued and encouraged.

The Tennessee Valley Authority is also operating an acid plant (pilot plant size) producing alumina from kaolin. However the product is not nearly pure enough for use in the manufacture of aluminum. Recent improvements in the purification of the aluminum sulphate solutions are expected to correct this situation, at least in great measure.

Use of Alunite

The mineral alunite, a hydrous potassium-aluminum sulphate, has received much attention as a potential source of aluminum, especially since large deposits of high grade ore have been reported. At present there is in operation by Kalunite, Inc., a pilot plant near Salt Lake City, funds for which were supplied by the Defense Plant Corp. on recommendation of the War Production Board.

Kalunite, Inc., is proceeding with an acid plant for the production of alumina from alunite. It seems probable that it can treat, to advantage, two to three tons of clay for each ton of alunite without using more sulphuric acid than can be obtained from the sulphur in the alunite. This should be another method of obtaining alumina from clay.

It is the opinion of this Committee that the Kalunite process or other processes dependent on the utilization of potassium alum are the best available acid processes for the production of alumina. The Morenci tailings project,

work on which is being sponsored by the Defense Plant Corp. through the War Metallurgy Committee, comes within the classification of a potassium alum process.

Need for New Processes

It would appear that the time is at hand when the domestic bauxite should be conserved. This involves other things than aluminum metal. For instance, in the manufacture of most alumina abrasives a substantial amount of a special grade of low-silica bauxite is desirable, if not necessary. To minimize this consumption it may be desirable to earmark the required amount of the proper grade for such abrasives as are essential in the war effort.

Most of the aluminum sulphate manufactured in the United States is made from bauxite, but the Committee is informed that at least one company is making it from calcined clay. Apparently, large quantities of bauxite could be conserved and made available for the manufacture of alumina by restricting its use in the manufacture of aluminum sulphate. For use in small plants the clay could be calcined at some central source. A minor point is that the siliceous residues from clay would be more bulky than from bauxite, possibly necessitating additional settling equipment.

A pilot plant, operated by Aluminum Co. of America, is now studying the lime-soda process to secure data for the design of the Defense Plant Corp.'s alumina plant. It is recommended that this work be given sufficient priority assistance so it can determine, among other things, the maximum amount of clay which could be used in conjunction with a Bayer plant. The Committee considers this one of the most important projects in connection with the production of alumina from domestic raw materials. If large quantities of clay can be used for feed in a combination Bayer-lime-soda plant, this should be a most economical way to produce alumina from clay and a minimum of new plant construction would be required. Furthermore, this system of operation will conserve bauxite, making the limited domestic supply last longer in proportion to the amount of clay that can be successfully treated. Until information is available on the amount of clay that can be used in a combination plant, it will not be possible to accurately determine either the size or the nature of additional facilities for the production of alumina from clay.

"FISH-EYES" IN STEEL WELDS

CAUSED BY

HYDROGEN

By Carl A. Zapffe
Research Metallurgist
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Columbus, Ohio

TO HOW MANY, I wonder, has come some philosophical appreciation of the fact that temperature is the most powerful single determinant of both the physical and the chemical properties of the universe; that the world as we know it—composed of certain proportions of gases, liquids, and solids—is restricted in its very existence to a comparatively minute range of temperature lying far above those temperatures at which all substances are solids, and much further below those at which all are gases?

Such an appreciation can be important in developing our understanding of the phenomenal effects of gases in metals—in the present case, hydrogen in iron and steel. Only two more basic facts require recognition: (1) That supersaturation of any alloying element leads to precipitation, which includes the much discussed aging phenomena; and (2) that all defects caused by hydrogen in iron and steel, practically speaking, are the result of high pressures of gaseous hydrogen trapped at internal surfaces where it has precipitated. It should also be remembered that, while hydrogen is soluble in iron to a certain extent, hydrogen and iron form no known chemical compounds.

To carry our introductory philosophizing to its useful conclusion, suppose that life was being lived at temperatures near absolute zero, some 550° F. lower than in actuality. Gases and

liquids would be non-existent. Hydrogen would be a solid; and, we have reason to infer, a metallic solid. Iron-hydrogen alloys might then be used to good purpose, for most of the defects we are to consider could only occur upon heating that alloy to some temperature above, say, 0° F., where hydrogen is a gas. As a matter of fact, at the lower temperature, supersaturation of a metal with hydrogen "metal" might lead to valuable age-hardening effects. At ordinary temperatures, the same precipitation of hydrogen leads to the trapping within the metal of gaseous molecules which require a ten-thousandfold greater *Lebensraum* than the hypothetical metallic hydrogen because their phase is gaseous. It is the compression of that gaseous phase into the restricted spacing of crystallographic precipitation planes that causes embrittlement of the host metal; whereas at non-crystalline centers, such as inclusions and deformities, blistering or granular disintegration may ensue, along with surrounding embrittlement.

The naturalness of the hydrogen phenomena can be further clarified by again figuratively transposing ourselves, this time into a high temperature range in which many elements known to us as metals would be gases. Consider some system like barium in tungsten that probably would show aging characteristics upon cooling from 4000 to 3000° F.—as predicted from the shape of the solubility curve. Barium is a gas at those temperatures, although its solution in tungsten would constitute a solid alloy phase just as hydrogen is known to do in iron 2000°

below. Upon precipitating during cooling from 4000 to 3000° F., however, the free barium would necessarily revert to its gaseous condition, and the tungsten would be stressed internally just as iron is stressed by precipitated, trapped hydrogen.

This phenomenon of internal aerostatic stresses from the precipitation of elements whose natural state for that temperature is gaseous must therefore be expected and understandable. The general conception is ideally illustrated by the iron-hydrogen system simply by shifting the well known solubility curve for hydrogen in iron under one atmosphere pressure to the axes for familiar alloy equilibrium diagrams, as shown in Fig. 1. The characteristics of an age-hardening system—that is, a lowered solubility at lowered temperature—are visibly strong all along the heavy-lined curve, with especially important precipitations indicated at the solidification and transformation temperatures.

The alloy of hydrogen and iron, then, is of the same type as those other alloys of iron wherein the alloying element has a limited solubility that decreases with decreasing temperature. There is only one important difference: The hydrogen-iron system, from the standpoint of the phase rule, has one more variant, pressure. Thus the composition of iron-hydrogen alloys is determined not only by temperature, but also by the partial pressure of the soluble hydrogen atoms.*

Because pressure is a variable in the iron-hydrogen alloy system, its complete study would constitute a valuable contribution to the study of aging. The equilibrium conditions for the transformation of atmospheric hydrogen H_2 into dissolved atomic hydrogen $[H]$ are simple, and the fact that it dissolves in iron only as atoms is well established. Consequently, the relationship of extra-lattice molecular pressures to intra-lattice atomic concentration can be calculated directly. Beginning at an elevated temperature with a given concentration of hydrogen atoms in iron, one can find the pressure of extra-lattice molecular hydrogen that

*To alloy barium with tungsten at temperatures above the boiling point of barium, gas pressure would play the same role as in the iron-hydrogen alloys.

must develop to prevent further precipitation at any given temperature during cooling by the following considerations:

$$H_{2(\text{atmospheric})} = 2H_{(\text{atmospheric})} = 2H_{(\text{in iron})}$$

$$P_{(H_2)} = k[H_{\text{in iron}}]^2$$

A decrease in solubility of tenfold, as caused by decreasing temperature, therefore brings a hundredfold increase in the precipitation pressure of hydrogen in iron. Since the solubility may decrease by a factor of many hundreds throughout the ordinary course of cooling of steel, pressures exceeding the strength of the steel are quite readily attained. Precipitation pressures of similar magnitude must occur in the aging phenomena due to separation of solid phases, but no such tool is convenient for their calculation.

Especially does the precipitation pressure rapidly attain enormous values in the elastic range for steel, which may explain the extreme sensitivity of certain steels to "flaking" and "cracking" within limited ranges of moderate temperatures. To illustrate the conditions three dot-and-dash lines have been superimposed on the solubility curve in Fig. 1, showing the precipitation pressures calculated for iron-hydrogen alloys containing only 0.0025, 0.0005,

Fig. 1—Transposed Solubility Curve for Hydrogen in Iron Under One Atmosphere Pressure, Showing Unusual Precipitation or Aging Characteristics. The superimposed dot-dash curves represent the calculated precipitation pressures developed during the cooling of iron-hydrogen alloys containing only 0.0025, 0.0005, and 0.0002% hydrogen by weight respectively, which correspond to alloys C, B and A respectively. Note that stresses quite sufficient to deform steel are probably developed even in the 0.0002% alloy before it cools to room temperature.

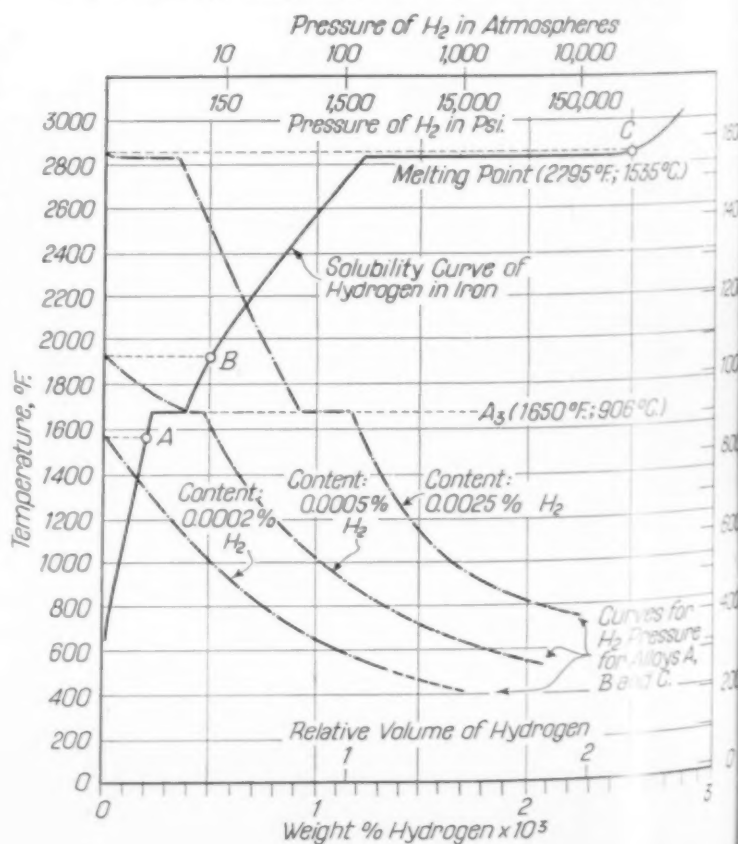




Fig. 2—Tensile Fractures of Mild Steel Specimens That Had Been Embrittled Throughout by Annealing 2 Hr. in Hydrogen at 2000° F., Followed by

Quenching and Aging at Room Temperature as Indicated. Note the recession of the characteristic white fracture to the axis of the test piece

and 0.0002 weight % of hydrogen, respectively, which correspond to the alloys C, B and A marked on the solubility curve—alloys common in steel making. While actually the concentration of hydrogen in the iron lattice would decrease as the precipitation progresses, which will mitigate the final pressure, these curves agree with 70 years of investigation on the iron-hydrogen system that definitely assures us that steel-rupturing stresses do result from this gas with facility. We have embrittled iron by annealing in hydrogen at 1550° F. and one atmosphere pressure, which would produce the alloy A corresponding to the lowest dot-dash curve. (At lower temperatures, for the same pressure, sufficient gas is not absorbed to cause embrittlement.)

In published work from Battelle Memorial Institute, the tremendous forces and pressures built up by supersaturated hydrogen precipitating from iron—and at ordinary temperatures iron containing *any* detectable hydrogen is supersaturated with respect to the atmosphere we breathe—has been demonstrated in progressive degrees by bubbles in water, blisters in paint, chips in vitreous enamel, blisters in steel sheet, and blisters in steel plate. Finally, an artificial cavity drilled into a steel cylinder was fitted with a high-pressure gas gage. Made

cathodic in an electrolytic cell, the cylinder absorbed the nascent hydrogen through its 1/4-in. walls. The gas precipitated in the cavity; and, because it lacked a mechanism within the cavity to reverse the process, the gas collected under several hundred pounds per square inch when the experiment was interrupted for reasons of safety. Other investigators have obtained pressures of nearly 5000 psi., and in no case has the rate of infusion shown any retardation, nor has back-diffusion appeared. The only limits to the pressure obtainable are purely personal, for the specimen effectively becomes a bomb!

"Flakes" and "Fish-Eyes"

Among the earliest recognized and the most widely discussed features of hydrogen in iron and steel, lowered ductility stands foremost. Frequently investigators have mentioned the "coarsely crystalline fracture" surrounded by normal fibrous metal in tensile and impact specimens showing "flakes", "snow-flakes", "fish-eyes", and such variously named seats of hydrogen embrittlement. Truly, the hydrogen maladies in ordinary steels can be immediately recognized by that outstanding characteristic whereby the affected zones stand out brilliantly against the darker fibrous background.

In Fig. 2 and 3 are shown fractures of mild steel, enlarged about 2 times, of tensile specimens which had been embrittled throughout by annealing 2 hr. at 2000° F. in hydrogen. Immediately after treatment the fracture is silvery and coarsely granular. Note the return of fibrous frac-

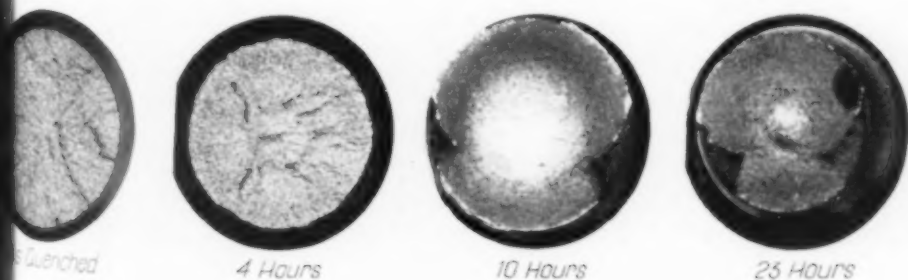


Fig. 3—Similar Tension Test Pieces (Enlarged About 2 Diameters) Embrittled in Hydrogen and Aged at 225° F., Whereupon Hydrogen Diffused Outwardly in a Day or so, Thus Restoring Ductility to the Steel

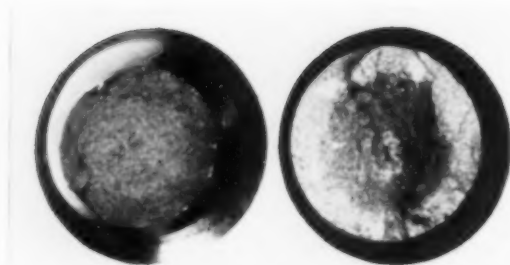


Fig. 4—Mild Steel Showing Reversed Conditions of Fig. 3 and 4. The specimen on the right was partially loaded with hydrogen during 1 hr. of cathodic electrolysis

ture in the exterior regions as the specimens aged for several days at room temperature, and the more rapid return of ductility when heated to a slightly elevated temperature. Of course the last portion to become ductile is the center, because the concentration or diffusion gradient is from core to rim. The reverse effect is illustrated in Fig. 4 by a normal ductile specimen which was made cathodic in an electrolytic cell for 1 hr. The progress of the "critical" quantity of absorbed hydrogen is easily followed by the white rim.

Commercial occurrences of the defect are rarely so geometric with respect to the external surface of the specimen, but they show similar symmetry about heterogeneities within the metal, such as blowholes, inclusions, and interdendritic voids, or banding discontinuities. These give rise to the "fish-eye", "snow-flake", and "silver streak", respectively. Snow flakes in a test piece of commercial steel are shown in Fig. 5 at 4 diameters. The observed surface, of course, is only a small section through an extensive embrittled zone, and somewhere within that zone—not necessarily exposed at the fractured surface—is a slag stringer or some such discontinuity around which the hydrogen collected and from which it will ultimately diffuse.

The defect can be produced artificially quite easily, as illustrated in Fig. 6. There a tensile specimen of mild steel was coated with glyptal except along four thin longitudinal lines at quadrant positions. Made cathode in an electrolytic cell, the specimen absorbed hydrogen

along the four lines where the iron was exposed, and subsequent fracture resulted in producing four artificial snow-flakes. An incidental observation of some interest is that, from the standpoint of hydrogen concentration and diffusion, the surface of this electrolyzed specimen corresponds to the internal surface of a naturally occurring snow-flake or fish-eye. Thus, this artificial embrittlement actually represents only a sector of a snow-flake whose center is at the surface of the specimen.

Three types of hydrogen embrittlement are illustrated by the fractured weld specimens in Fig. 7. The specimens on the left are brittle throughout; the central specimens show the silver-streak type of embrittlement where hydrogen has accumulated at the interbead junction of a two-bead weld; and on the right the welds show "fish-eyes", which are local embrittled zones surrounding small blowholes or inclusions.

Better reproductions of fish-eyes appear in Fig. 8.

In the latter photographs one can readily note that the embrittled zone surrounds a blow-hole whose shiny interior also suggests the presence of a reducing gas such as hydrogen. The radial markings may or may not be cracks, and have in themselves caused heated and needless argument; in the present illustrations most of them are simply sharp vertical steps, probably occasioned by differ-

ences in the grains composing the brittle zone. I know of no case wherein the gas pressure in itself has caused a macro-fissure, for the pressure is

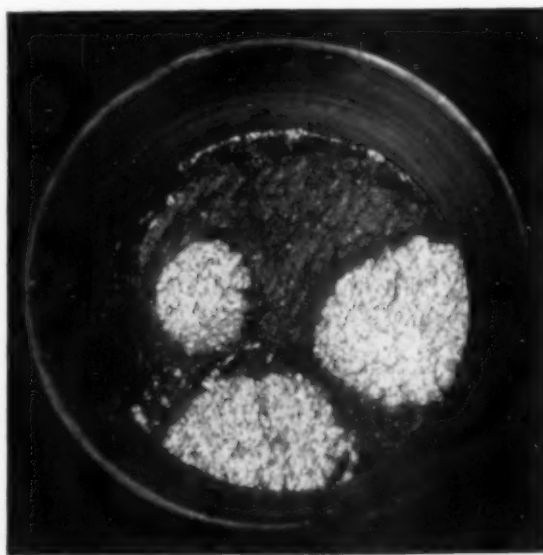


Fig. 5—Snow-Flakes in Tension Test Piece of Commercial Steel. Magnified 4 diameters

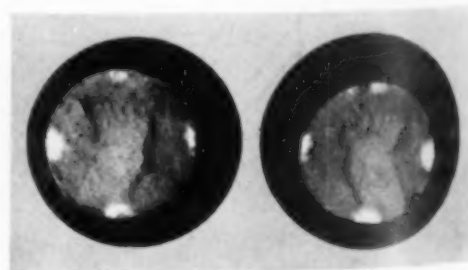


Fig. 6—Artificial Snow-Flakes on Tensile Fracture Produced by Loading Mild Steel With Hydrogen Electrolytically at Confined Quadrant Positions. Magnified $1\frac{1}{2}$ diameters

relieved, long before a visible crack need form, by escape of the gas through intercommunicating slip and cleavage planes opened by the precipitation phenomenon and by increased pressures from subsequent heating. When cracks definitely exist *before* an external load is applied to the brittle steel (as by breaking the test piece) they are more readily attributable to intrinsic stresses developed by the metal itself, most probably by temperature gradients or by volume changes occurring over a transformation range.

Essential Causes of Brittleness

It is a peculiar fact that no explicit account appears ever to have been given for the brightness that ostensibly belongs to the fracture of iron embrittled with hydrogen. Of course the erroneous assumption, so long held, that iron forms a hydride undoubtedly retarded thought along these lines because hydrides are notoriously brittle. The coarsely crystalline appearance of fractured brittle substances has been accepted *a priori* since a time so immemorial that to question the true nature of brittleness now is almost iconoclasm.

Nevertheless, the question: "Why is the fracture of hydrogen embrittled iron shiny?" was faced at the outset of the studies on metal-

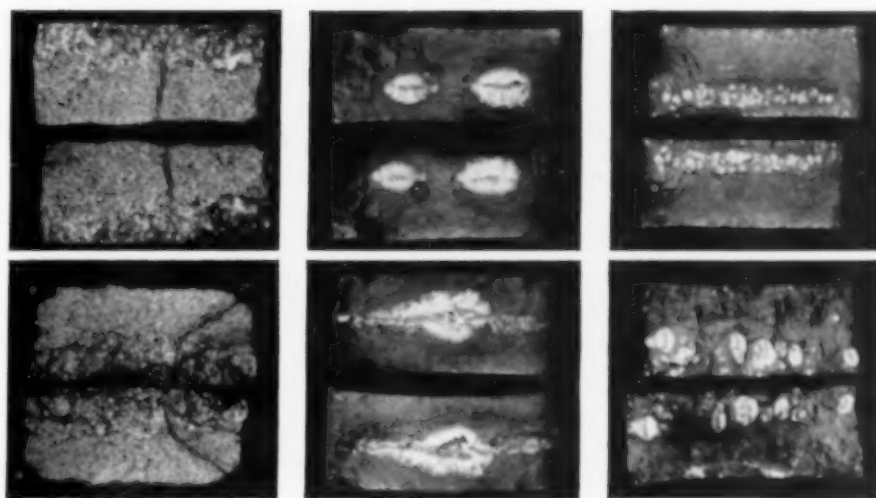


Fig. 7—Tensile Fracture Through Weld Metal, Illustrating Three Visual Types of Hydrogen Embrittlement. Full size. At left is completely embrittled metal, at center is "silver streak", at right are "fish-eyes"

lic defects at Battelle Memorial Institute. Although the fascinating developments of that inquiry are still in an exploratory stage, some of the results can be skeletonized.

First, conceptions of crystalline structure developed in several widely separated fields of research were found to coalesce. For example, those investigating hydrogen in steel agree that iron at room temperature cannot hold more than 0.01 relative volume (or 0.00001% by weight) of hydrogen in true solution under one atmosphere of hydrogen. Yet, quantities over 20,000 times that great have been found, and several thousandfold greater contents are quite common. Iron's amazing capacity for occlusion can be simply demonstrated by pickling thin steel wires in 10% H_2SO_4 and subsequently immersing them in a warm liquid, such as gas-free water near its boiling point. Immediately a cloud of hydrogen bubbles arises from the wire, and the action does not stop for several minutes. Yet this effusion, it has been quite well established, represents only a small fraction of the total quantity of gas absorbed by the small steel wire when it was attacked by the acid during the pickle.

It therefore appears that the major portion of the gas occluded at ordinary temperatures must be "extra-lattice". For pure iron, that means the gas is held in internal voids. Blow-holes and visible hiatuses cannot be considered, for long ago it was proved that sound steel may actually hold more hydrogen than porous steel! What is the seat of occlusion, then?

An immediate answer stands in the work of SMITH and his co-workers at Princeton Univer-

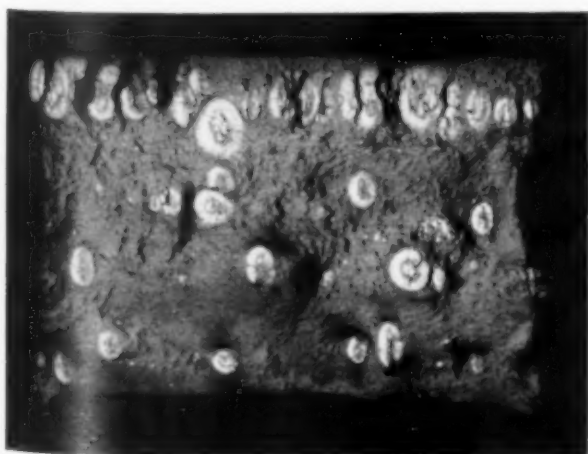
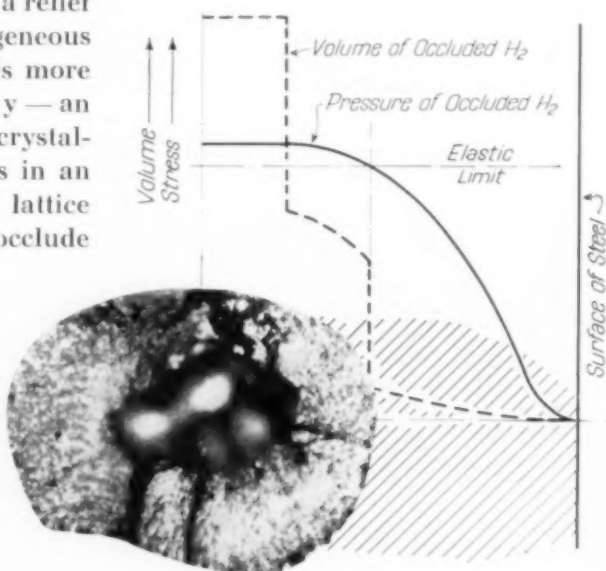


Fig. 8—An Unusually Fine Example of Fish-Eyes in Fractured Weld Metal, Magnified 3 Diameters

sity, who showed that hydrogen in nickel and palladium collects in internal rifts that are crystallographic and correspond with deformation planes. If a specimen of these metals is loaded with hydrogen, coated with a transparent liquid, and deformed, bubbles of the gas visibly escape from the deformation lines. The same is true for iron, though the observation is more difficult because of the complexity of the deformation mechanism. Apparently we must amend the popular conception of a slip plane as a figmentary locus and a slip line on a polished surface as a relief effect caused by homogeneous shear. The slip plane is more likely a heterogeneity—an actual disjunction of crystallographic characteristics in an otherwise homogeneous lattice—for that plane can occlude

Fig. 9—Fish-Eye, at 15 Diameters, Enclosing Bright Cavity Suggestive of Bubble of Reducing Gas. Schematic diagram shows the probable volume and pressure relationships for hydrogen, from interior of fish-eye to surface of the specimen



precipitating hydrogen in astonishing quantities, quantities that clearly prove that the gas must also be under pressures approaching, and in many cases exceeding, the known elastic strength of steel. I use the word "elastic" advisedly; I imply that hydrogen occluded under sufficient pressure at those planes "springs" them open and locks the surrounding lattice blocks against further motion, the result on strength and ductility being similar to the effect of cold work beyond the elastic limit.

"Mosaic Structure" of Crystals

These facts are fairly well established. Another matter, afforded by physicists, also belongs in this picture, and that is the conception of "mosaic structure", wherein metal crystals are assumed to be composed of ultra-microscopic and crystallographic structural units, often called "blocks". Though we can avoid discussing the moot details in the argument over the exact nature of the "block", we choose to accept the rudimentary picturization

because it provides an intrinsic and orderly relationship among many phenomena often regarded separately, such as deformation markings and progressions, the "rift occlusion" of hydrogen, Widmanstätten pattern and eutectoid precipitations, etch pits and their markings, "active centers" in catalysis, anomalies in X-ray diffraction, and possibly the magnetic Weiss domains—to recall but a few from many.

In Fig. 9 the foregoing discussion is generalized in a schematic diagram superimposed upon a photographic enlargement of a fish-eye. Briefly, we regard the shiny, central blowhole as the locus to which hydrogen diffused during cooling, because a surface was immediately available for precipitation of the gas from the surrounding metal, and from which the gas later diffused when the longer gradient to the atmosphere became effective. The gas within that blowhole was under a maximum pressure, such that in every available deformation disjunction

(slip and cleavage planes) for a certain distance surrounding that locus, the aerostatic pressure of the trapped gas was sufficient to "spring" the mosaic units and prevent their performing the movements that confer ductility upon metal.

The brilliant crystalline zone surrounding the blowhole, then, so long without satisfactory explanation, simply comprises the flat, crystallographic surfaces of large groups of these blocks which have been immobilized and partly separated by the interned gas. Ordinary "fibrous" fracture is also transcrystalline, but shifting and rotating of the blocks destroy the orderly group arrangement so that individual facets on the fracture are too minute to give a bright appearance.

The gas pressure within the entire fish-eye, as shown in the sketch, probably exceeds the elastic, or cohesive, strength of the metal. At the boundary—the edge of the bright zone—the forces are equal, and from there toward the atmospheric surface the interior gas pressure must dwindle, at no time being able to inhibit slip and thereby to lower the ductility. ☉

A METHOD OF SAMPLING FOR METALLURGICAL TEST PIECES

By C. T. Eakin
Feeder Engineering Division
Westinghouse Electric & Mfg. Co.
East Pittsburgh, Pa.

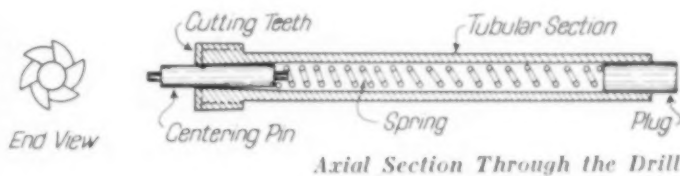
IN THE RACE to increase production as quickly as possible, yet maintain quality, engineers, inspectors and others responsible are often called upon to accept or reject castings or wrought parts with inadequate information concerning the metal or samples for testing same. Of all the investigational methods, the one which generally yields the most pertinent information for least amount of sample is probably the study of metallography under the microscope.

There has been a need for a practical tool for sampling large pieces which would be simple and rapid, yet which would not impair the usefulness of the object for its intended purpose. Spot polishing and bringing the microscope to the piece has numerous disadvantages. The requirements are fulfilled for many applications in the core drill now to be described.

The drill consists essentially of a tubular member having a number of cutting teeth at one end, and a removable centering device inside the tube consisting of a pin and a spring. It can be used in any ordinary drill chuck and operated in a stationary drill press or in a portable air, electric, or hand drill. The drawing shows an

axial section through the drill, and the assembly of auxiliary parts.

Before using this tool, a small $\frac{1}{16}$ -in. pilot hole about $\frac{1}{8}$ in. deep is first driven with a standard twist drill in the location selected for the specimen. The core drill is then clamped in the drill chuck and inside this tubular member is inserted first the spring and then the centering pin. (In some types of chuck a plug, which may be of any material, is necessary in the upper end of the tubular member to serve as a stop for the spring.) When in position, without pressure on the spring, the centering pin should protrude a small amount, as shown in the sketch. The nipple of the centering pin



is then placed in the pilot hole and enough pressure applied to compress the spring and cause the tubular member to slide down over the pin until the cutting teeth contact the object to be sampled. A light pressure is then applied and rotation of the drill started.

When drilling has proceeded to a depth of

about $\frac{1}{16}$ to $\frac{1}{8}$ in. the centering pin and spring — their function of centering the drill at the start having been accomplished — may be removed by simply raising the drill and permitting them to drop out. The core drill may then be reinserted and drilling carried to required depth. The drill is withdrawn and the core broken off at the bottom by flexing the core until it breaks. Shavings, if cleanly collected, are suitable for chemical analysis.

Such a core drill can, of course, be started by using an ordinary drill jig, but this might require a special jig for each new location, whereas no jigs are required with the method just described.

Another method for starting core drills consists of first drilling a starting hole with an ordinary twist drill the size of the outside diameter of the core drill, and then starting the core drill in this shallow hole. This method, however, destroys the surface material which is often desired for micro-examination. Our centering pin method produces a core, a part of which extends entirely to the surface.

The time required to obtain a core sample is usually short. For example, when sampling forgings for both chemical analysis and micro-examination, using a $\frac{3}{8}$ -in. twist drill for analytical sample and $\frac{3}{8}$ -in. outside diameter core drill for the metallurgical specimen and a portable electric drill in both cases, one operator found that it required slightly less time to drill a hole 1 in. deep with the core drill than with a twist drill of the same size. If we compare this with the slow and laborious method of sawing out the microspecimens, which is so often employed, the core drill method is comparatively rapid.

Utility of the Tool

The tool is also versatile. It is adapted for use with common drilling equipment such as is to be found in any machine shop. Used in a portable power or hand drill, specimens can be taken from any desired position on the object being sampled, no matter whether it is located in the factory or field.

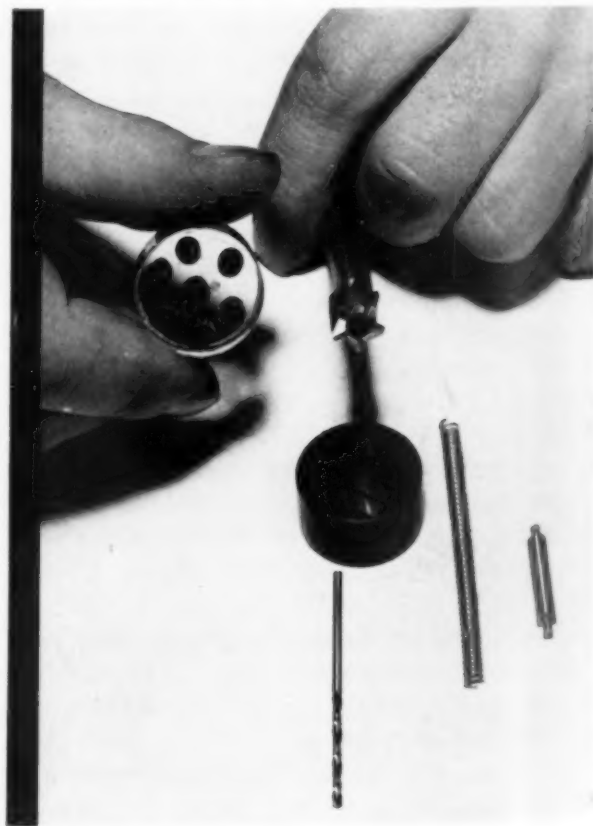
Turning our attention to the use of the core drill for obtaining specimens from objects without impairing them for their intended purpose, let us, for convenience, divide the metals used in industry into two groups. One group consists of objects from which absolutely no material can be removed without impairing

their usefulness. This group plainly is hopeless for our purpose. The other group consists of objects from which material will be machined or drilled, or which have regions of light stress from which small samples of material can be removed without harm, yet whose structure is representative of that in the critically stressed section. This group offers opportunities for non-destructive sampling for microstructure with this tool.

When suitably mounted, as for example by molding in plastic as shown below, the specimens can be readily tested for hardness by Rockwell or Vickers machine. Hardness can be determined not only at the surface but at any location down to the base of the core.

The size of the drill may be varied according to such circumstances as the purpose of the test and the kind and the amount of available material. With drills of suitable size, tensile tests may be made from the core, but in most cases the information from the microstructure plus the approximate tensile strength indicated by the results of the hardness test is sufficient. ☺

Component Parts of the Core Drill Including the Small Twist Drill Used for Pilot Hole. At the left hand are seven core samples mounted in transparent plastic, polished in transverse section and tested for hardness. In the opaque block are four specimens polished longitudinally



SIMPLIFIED ELECTRO-POLISHING OF STEEL SPECIMENS

By **R. Wayne Parcel**
Metallurgist
Denver & Rio Grande Western Ry.
Denver, Colo.

TECHNICAL LITERATURE during the past two years has contained many articles on the electro-polishing of metals, notably iron and steel. The labor-saving possibilities of the method seemed so great that the Denver & Rio Grande Western Railroad Laboratory purchased necessary equipment and installed a motor-generator set very shortly after the appearance of the first paper. However, attempts to replace hand polishing with electro-polishing for routine microscopy met with indifferent success, although it was demonstrated that with sufficient care and attention, highly satisfactory polishes could be obtained.

The early methods were critical in several respects, primarily as regards current density, and it was found that the average laboratory helper spent almost as much time in preparing a given set of samples electrolytically as he did by hand methods. This experience is not confined to our own laboratory; we have found several others who were quite disappointed in the methods, and abandoned them entirely. We at the Rio Grande continued to try most of the new techniques which appeared in the literature, as well as a few of our own. The net result has been the development of a method and equip-

ment which, in our own estimation, far surpasses the older ones not only in speed but in reliability, and in the quality of the average polish. The best results of hand polishing versus electrolytic polishing (or of the various techniques of electrolytic polishing) seem quite comparable, but the method we present here comes much nearer to giving this best result on individual attempts.

We use a new and simpler solution which will polish steel or aluminum, as well as some of the other non-ferrous metals, in 20 to 30 sec., with only a grindstone for preliminary equipment. It is suitable for polishing pieces, in place, using a portable cell, and is so simple as to require no previous experience.

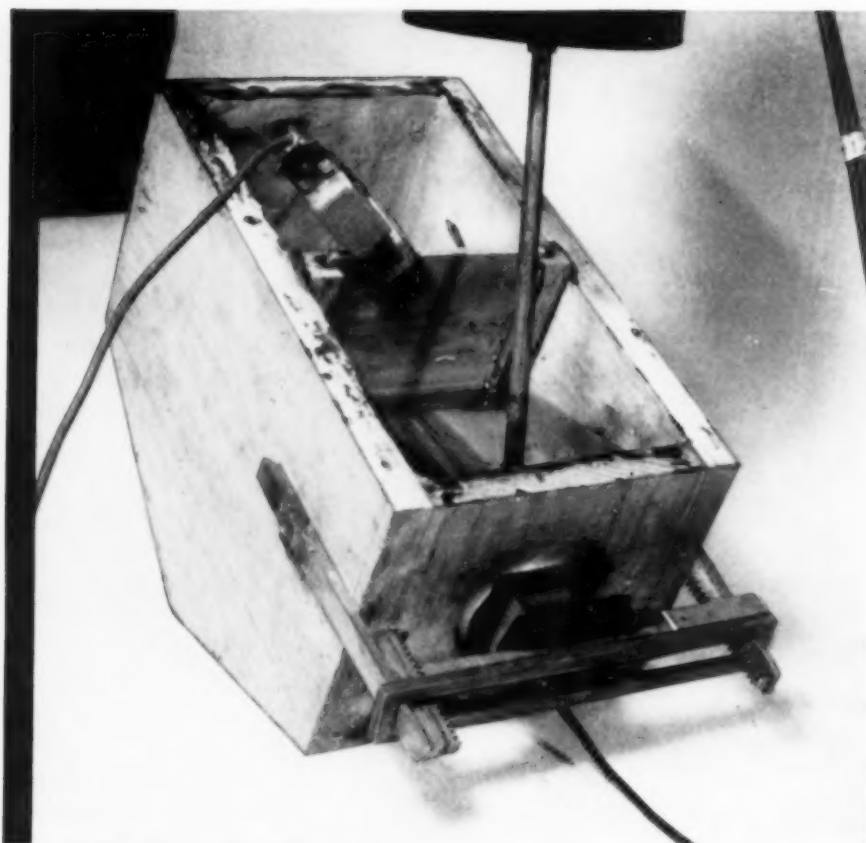
We have given the method a thorough try, and are using it in routine work. As a matter of fact, in the past six weeks we have polished nothing but cast iron and a very low carbon steel by hand methods. On the last named the solution produces such extensive pits that the sample is unsuitable for photographing, and we photograph most of our specimens for reports and records.

The solution is one suggested by DeSy and HAEMERS in *Stahl und Eisen*, 1941, page 185, and consists of perchloric acid, ethyl alcohol, water, and ether, in the following proportions:

Perchloric acid, 54 cc. of 70 to 72% concentration

Water, 146 cc.

Mixture of alcohol with 3% ether, 800 cc.



Tilting Box (Paraffin Coated) Used for Cell. Stainless steel cathode acts as central partition; vertical shaft in rear compartment carries a stirring vane and is driven from small motor held above by adjustable arm

M. E. MERCHANT (in METAL PROGRESS for May 1940) emphatically warns against the explosion hazard when perchloric acid is mixed with organic liquids, or comes in contact with lucite or bakelite mountings, or bismuth or its alloys. In mixing our solutions no heat is evolved. It can be "thrown together" in about 5 min. Our experimentation with various compositions is not yet complete; the above was the starting point, and is still our standard. We have found that almost any commercially denatured alcohol will work. It is suspected that the ether may act in much the same manner as various brightening agents in plating. Small amounts of glue will improve the polish on low carbon steels. We plan to try formaldehyde, and a number of other plating "brighteners", mostly colloids; so far the rush of work has prevented extensive experimentation.

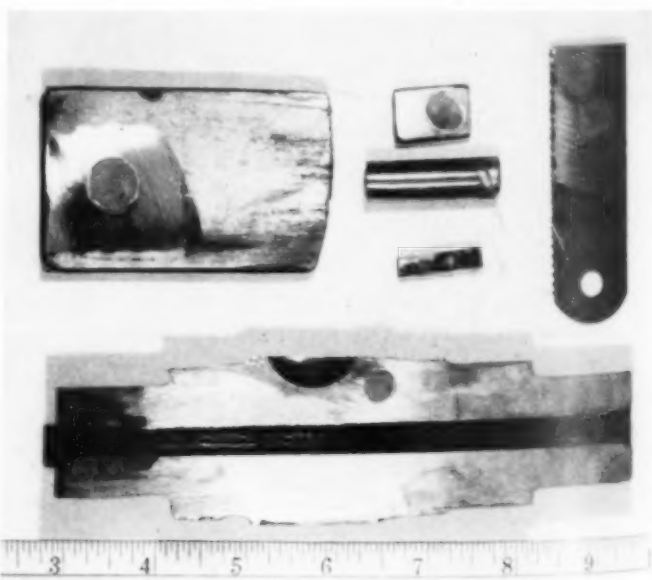
Current densities are of the order of 2 to 6 amperes per sq.cm. for steel and aluminum, and much lower for other metals. One complex alloy of copper, zinc,

manganese and nickel requires only 0.5 ampere per sq.cm. current density. It must be said immediately that few of the non-ferrous metals polish at all well with this solution, which is more or less to be expected.

Due to the high current densities, the area which can be polished is limited; therefore we have adopted a modification of the tilting cell described by BROWN and JIMISON in METAL PROGRESS (September 1941) to limit the area exposed. Equipment is shown at the left. A paraffin-coated box was fitted with a stainless steel cathode, and a hole cut in one end through which the specimen makes contact with the solution. A convenient ratchet clamp of considerable length enables us to handle pieces a couple of inches thick.

The cell has interior dimensions of 8×4×4 in. and

the sides extend beyond the flat bottom, sloping from either end to an angle at the middle. Thus the cell may recline in either of two positions, one of which leaves the hole in the front high and dry. We find



Various Sizes and Shapes of Specimens Polished in Tilting Cell. Round spots on the larger pieces are the polished areas

this arrangement easier to operate than the cell hinged at a lower corner, as recommended by BROWN and JIMISON. Other modifications include a gum rubber gasket between the specimen and hole, and a more positive clamping mechanism for the specimen. The rubber gasket prevents the paraffin lining from melting under the heat produced, and also permits the size of the opening to be varied by changing gaskets.

The rugged clamping arrangement permits quite heavy pieces, up to several pounds, to be held, and thus avoids much cutting to size. This clamp consists of two arms extending from opposite sides of the box and parallel to each other. One arm is hinged, and the inner sides of both carry short pieces of 24-pitch gear racks. A cross-arm carries a mating section of rack on each end and a brass loop holds them all together by connecting the hinged arm to the fixed one.

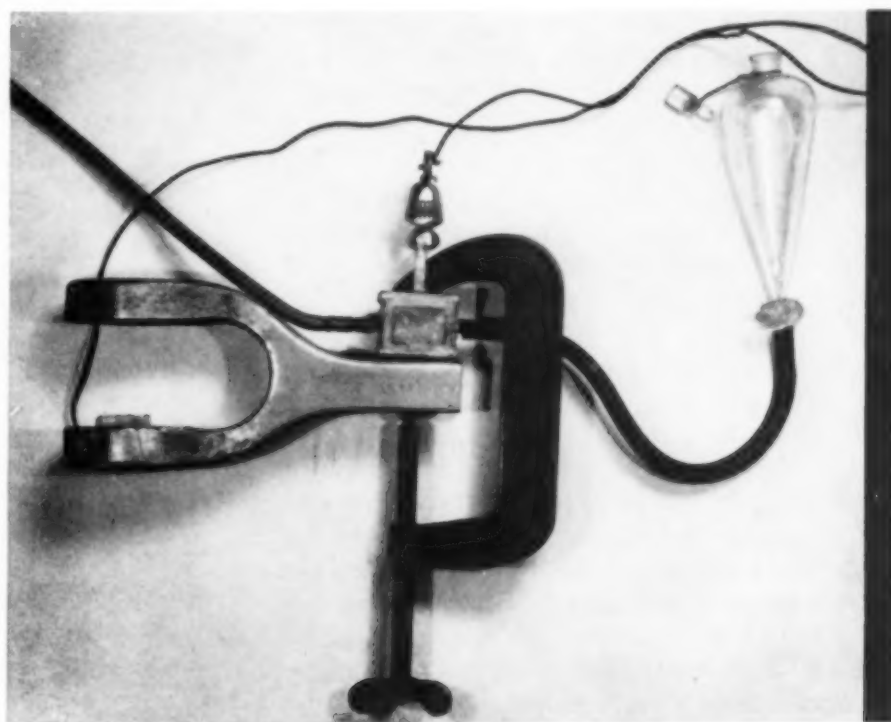
A specimen is prepared by grinding a flat on it with a 60-grit alundum wheel; it is then placed over the hole and gasket, and the cross-arm is put in place. A brass contact plate is inserted between cross-arm and specimen, and the hinged side arm is swung into position to mesh with the free end of the cross-arm. The hold-fast loop is then slipped over the side arms, and the cell is tipped forward so that the specimen's face is submerged. A stirrer is swung into position and turned on. When the solution is swirling, current is passed through the cell at a potential of about 70 volts.* After 20 or 30 sec. has passed, the generator is turned off and the polish is complete save for washing in alcohol. No etch is necessary. The entire cycle from grinder to microscope takes about 4 min.

If, during the polishing period, the needle

*The actual potential will vary with the dimensions of the cell and the spacing of the electrodes. Our spacing is 4 in. (end to center of cell). The potential is determined by increasing the voltage until the current "takes a nose-dive".

on the ammeter commences to oscillate jerkily, the generator should be turned off for 10 or 15 sec. because vapor is gathering on the specimen. Good circulation is necessary and for this reason the sample end of the box has been hollowed to a cone with the apex at the hole. The stirring rod is set quite near the specimen.

For those specimens which are too small to fit the end of the box, a different mounting is used. An electro-magnet operated from a battery holds them just touching the solution, and the cell is tilted to its other position. Polishing current can then be passed through the magnetic contact. The second view shows the variety of sizes and shapes which can be handled



Portable Cell, Attached to Steel Link, for Polishing Spots on Large Steel Surfaces to Be Examined in the Field With Portable Microscope

by a combination of the two techniques. The circular spots are polished areas; it obviously is unnecessary to polish an entire flat surface, for a small area can be masked off by the rubber gasket at the window.

On page 212 are two micros from these samples, the high speed steel hack saw blade and the hollow forged carbon steel pin.

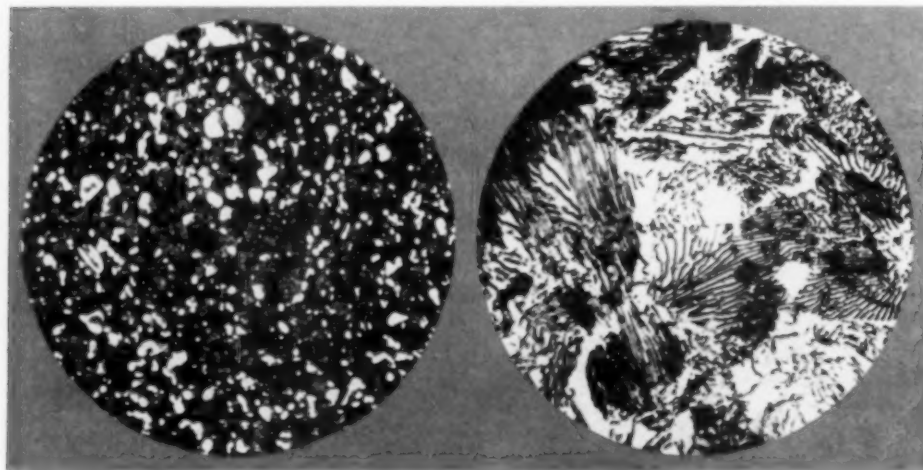
The obvious advantages accrued from eliminating the cutting of microscope specimens to small size led to a further step, and one which gives great promise, namely, a portable polishing unit. A very small electrolytic cell was

made, completely closed except for a $\frac{1}{2}$ -in. hole in one side. Pieces of copper tubing were inserted in holes drilled in two faces opposite each other, and an electrode built into the face opposite the polishing hole. This box may be clamped to a massive piece of steel, and a flow of solution maintained through it while polishing. A portable microscope is then brought up to the specimen and the structure may be examined. The arrangement is shown on page 211, attached to a forked end of a link. Our small portable microscope has no photographic attachments, so no micros are presented.

And now for a final word about operation: Greater success seems to come from watching voltage rather than current, once the proper potential is determined as described above. The original finish need be only a coarse grind for visual examination, but for photography at low magnifications it must be a flat, smooth grind. The solution, obviously, is a combination polisher and etcher—in other words, it has a very slight differential attack on the various microconstituents in steel. Only in a few instances—for example, very low carbon steel and some of the non-ferrous metals—need metallographic papers be used. Polishing cuprous metals in the bath ruins it for anything else, because copper plates out.

Little or no experience seems necessary. We have had men who had never prepared a micro try it with success the first time. Not one out of 20 specimens turns out unsuitable for visual examination and most of these are made good enough to photograph by repolishing the same area without further preparation.

The highest praise that can be awarded any method is this: That it works for visitors. Ours has yet to fail us!



PREVENTION OF CRACKS

in welded light alloy steel

By E. C. Rollason and A. H. Cottrell

Abstracted from Institute of Welding Quarterly Transactions, January 1941

THE PROBLEM of welding high tensile steels lies in preventing hot cracks in the weld and cold cracks in the hardened base material.

In the first part of the report an attempt has been made to obtain thermal data for two steels—a 6% Cr, 0.35% Mo steel and a 3½% Ni, 1% Cr, 0.35% Mo steel—and to appraise their effect on the cracking problem. The first essential was to obtain data on the effects of rates of cooling on the phase changes and the accompanying volume changes, and to relate these data to the propensity to cracking.

There is a sharp lowering of the critical temperature range A_r' as the initial soaking temperature is raised from 1435 to 1525° F. for the nickel steel and to 1650° F. for the chromium steel. Higher temperatures up to incipient melting have little effect on this. The practical application of this lies in the fact that the hot metal in the austenitic state does not transform to martensite until it passes through the critical range, and no subsequent heat treatment of the weld is likely to soften the heat-affected zone unless the metal is first of all allowed to transform to martensite. The austenitic zone of the base plate adjacent to a weld transforms to martensite at about 475 to 300° F. for the nickel steel and at 650 to 475° F. for the chromium steel, varying mainly as a function of the carbon content.

There are several methods of using such thermal data:

1. Heat plates to about 850° F., weld them, but prevent the temperature dropping below A_r' . Charge the welded article into a furnace at 1050 to 1375° F. (below the critical range on heating) to

(Continued on page 282)

Electro-Etched Specimens at 500 Diameters. Left is high speed steel hack saw blade; right is medium carbon steel forging

WAR PRODUCTS CONSULTATION

Fixing Bearing Metal in Steel Shells

The Problem

Raised by a Blower Manufacturer

IN VIEW of the tin shortage it has been necessary for us to remodel our fan bearings. Formerly we used about $\frac{3}{16}$ in. of tin-base babbitt (A.S.T.M. Alloy No. 3 or 10 parts tin, 1 part antimony and 1 part lead) and we are substituting the "emergency alternate" lead-base Alloy No. 16 (10% tin, 12.5% antimony, 0.5% copper, balance lead). We are having difficulty in attaching this metal to the steel backs. Bronze shells offer no difficulties, but bronze is also a strategic metal. Steel shells are not easily tinned; cast iron is nearly impossible to tin properly.

What we would be interested in would be a suitable method of treating the surface of the steel such as, perhaps, a new type of flux which could be relied upon to give us a good tinning job without installing much new equipment, as this would be unwarranted for our relatively small production.

Suggested Solution

An essential condition for alloying of metals at temperatures so low that one of them is hardly plastic is a clean—really *clean*—surface on the solid metal. Few commercial electroplaters realize this fact, or if they realize it, practice the art; consequently an electroplated intermediate layer would likely be unsatisfactory. The intermediate layer ("tinning" layer) might well be an alloy of 1 part tin and 2 parts lead; obviously the free tin in the mixture will alloy readily with *clean* steel,

and the free lead will alloy readily with the lead-base babbitt later cast on. Scale-free steel can be cleaned by degreasing, washing in hot water, pickling in an electrolytic circuit with the steel bearing back connected as anode, washing a couple of times with hot water and then immediately putting the clean, warm steel into the tinning pot.

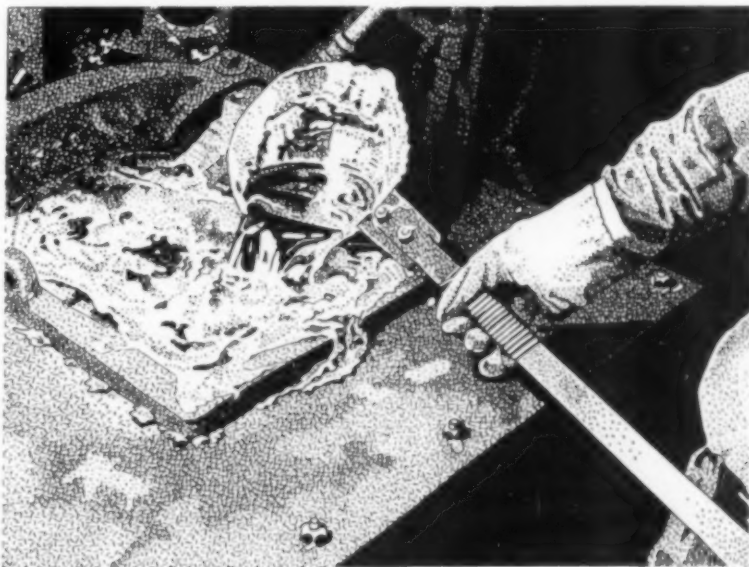
Critique

By John K. Anthony

Chief Chemist, Cleveland Graphite Bronze Co.

The following is a schedule of operations we have found satisfactory on many thousands of steel-backed bearings lined with A.S.T.M. Emergency Alternate Alloy No. 15 (1% tin, 1% arsenic, 15% antimony, 0.5% max. copper, balance lead). This alloy is also in the process of being adopted as a permanent specification by the S.A.E. and will be known by the number S.A.E.-15. The alloy ingot is marketed by the Federated Division of the American Smelting and Refining Co. and is designated by the Cleveland Graphite Bronze Co. as Specification F-23.

1. Steel: We prefer an S.A.E. 1010 or 1015 steel although 1020 has proven satisfactory. We have never used cast steel for this particular purpose but believe there would be no difficulty provided the analysis is correct. The surface to be



bonded should be well machined; by this we mean the cutting tool should take an actual cut on the final operation and not burnish or glaze the surface in any way. The machined surface should be fairly smooth, as a rough surface is more difficult to clean.

2. **Cleaning:** The steel shells should be cleaned in an electrolytic alkaline cleaner for at least 10 min. The work should be made the anode and the temperature of the cleaner should be at least 180° F. If a cutting oil has been used it is particularly difficult to remove the residual oil or sludge with an alkaline cleaner; this cleaning procedure may then be preceded by a vapor degreasing operation.

3. **Rinse** in cold or hot running water.

4. **Pickle** in 10% sulphuric acid for from 10 to 15 min. at 150 to 160° F. Work is placed in rubber-coated baskets between carbon electrodes, and alternating current imposed. (The work does not make contact with either electrode.) The alternating current used is 6 to 10 volts and the current density is approximately 35 amperes per sq.ft. The pickle tank must be rubber-lined.

5. **Rinse** in cold running water.

6. **Boil in water** for 1 hr. to remove any hydrogen absorption; pH is maintained at about 6.

7. **Fluxing:** The shells are dipped in flux composed of a 50° Bé solution of zinc chloride to which has been added approximately 3% salammioniac and 0.5% hydrochloric acid.

8. **Tinning:** The shells are then tinned by immersing in a coating material consisting of 35% tin and 65% lead at 600° F. The shells should not be removed until they have reached equilibrium temperature and all bubbling has ceased.

9. **Molding:** The shells are then placed in a mold made of gray cast iron which has been heated to between 350 and 400° F. The core of the mold should be hollow cast iron. The mold should be so designed that a head of metal of at least $\frac{3}{4}$ in. is provided after pouring.

10. **Casting:** The bearing metal is heated to 950° F. before pouring. Use an under-feed ladle. As soon as the mold is poured, puddle the molten material with a thin piece of iron wire which has previously been tinned. A thin sliver of dry hardwood may also be used to help eliminate gases and resultant blow-holes.

11. **Cooling:** The casting should be cooled from the bottom and the outside. This may be done by placing the whole assembly in a shallow pan and pouring a very small amount of water into the pan, after casting, adding more as it evaporates. This will cool the bearing from the bottom and if a hollow cast iron core is employed, the outside should cool faster than the inside. In other words we want to cool the bearing material from the steel side and not the running side. This process may further be aided by wrapping wet rags around the outside of the steel shell or mold.

THE INFLUENCE OF TIN on alloy steels*

By G. R. Bolsover
and S. Barraclough

AN INSTANCE of a cast of alloy steel with impact values lower than normal was encountered, and an investigation into the cause of this brittleness led to the conclusion that this might be due to a content of tin greater than would usually be present.

A careful search of the literature revealed very little information relative to the influence of this element on carbon steels and none concerning its effect on alloy steels. Consequently, it was decided to make a brief general survey of the influence of tin on some of the alloy steels most commonly employed in England.

The steels selected were the manganese-molybdenum, 3½% nickel and 3% nickel-chromium qualities as representative of steels for oil hardening and tempering, with a 0.35% carbon steel, without any alloying element, included as a basis for comparison. Compositions aimed at, and reached within narrow limits, are shown in the table. In all the steels silicon was close to 0.20%.

Analysis of the Steels Tested

STEEL	C	MN	NI	CR	MO	DATA
Carbon	0.35	0.75	0.07	Tr	—	Fig. 1
Mn-Mo	0.35	1.50	0.08	Tr	0.25	Fig. 2
3½% Ni	0.35	0.65	3.40	0.01	—	Fig. 3
Ni-Cr	0.30	0.55	3.10	0.80	—	Fig. 4
Ni-Cr-Mo	0.30	0.65	3.10	0.80	0.25	Fig. 4
Cr-Mo	0.30	0.50	3.10	3.15	0.55	Fig. 5

sulphur 0.02% and phosphorus 0.02%. (A high phosphorus series — 0.045% — was also prepared and was described in the original article.) Tin varied from 0.02 to 0.50%.

Small ingots, 2 in. square, weighing 18 lb., were cast from a high frequency furnace, forged to $\frac{7}{8}$ -in. rounds, heat treated and tested.

Impact results of the low phosphorus series are shown in graphical form. As will be appreciated, in the manufacture of nearly 70 different samples, slight variations from the composition required are liable to occur. All the steels, however, were tested and all the results, even though certain casts had one or more elements outside

*Abstract of preprinted paper, dated May 1942, issued by British Iron & Steel Institute.

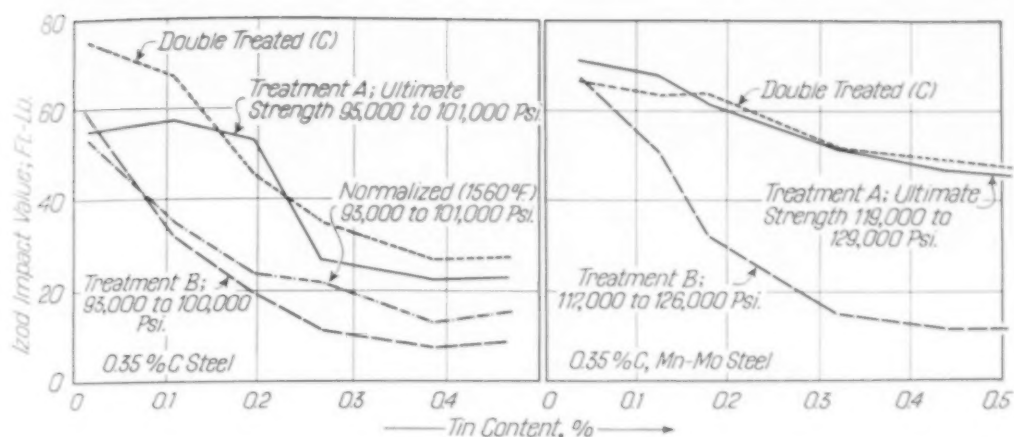


Fig. 1 and 2 — Influence of Tin on Izod Impact Value of 0.35% Plain Carbon Steel and Manganese-Molybdenum Steel. Treatment A is oil quench from 1560° F., temper at 1200° F. and oil quench. Treatment B is same except furnace cooled from tempering heat. Treatment C is B followed by a second tempering at 1200° F. and oil quench

the desired range of composition, are reported in the tables in the original article, but for the graphs only those steels within fairly narrow limits have been selected. To decide whether a steel should be included in a graph, judgment was based more on the tensile strength than on detailed composition, provided that the latter was within reasonable limits of that desired. In view of this, and in order to indicate readily the degree of variation, the range of maximum stress for each type of steel in each condition of heat treatment has been stated on the graphs.

On all the hardened and tempered steels examined, the influence of the presence of tin at even 0.1% is shown on notched-bar impact tests. Influence on the tensile results is relatively minor. It is interesting to note in the case of the basis carbon steel (Fig. 1) that this change in impact

values is not so marked when oil quenched after tempering (Treatment A) as it is in the normalized condition. On the alloy steels the effect of tin additions appears to be counteracted very appreciably by the addition of 0.25% of molybdenum.

The higher phosphorus steels, in general, give lower results than the lower phosphorus steels, but on the data available this appears to be more in the nature of a lowering of the impact value owing to the phosphorus content rather than due to any increasing effect of tin on the high phosphorus as compared with the low phosphorus steels.

The effect of tin on the chromium-molybdenum nitriding steel, as shown in Fig. 5, again appears to be counterbalanced to some extent by the addition of molybdenum, but the lowering of the impact value of samples containing a little tin is very marked after a nitriding heat.

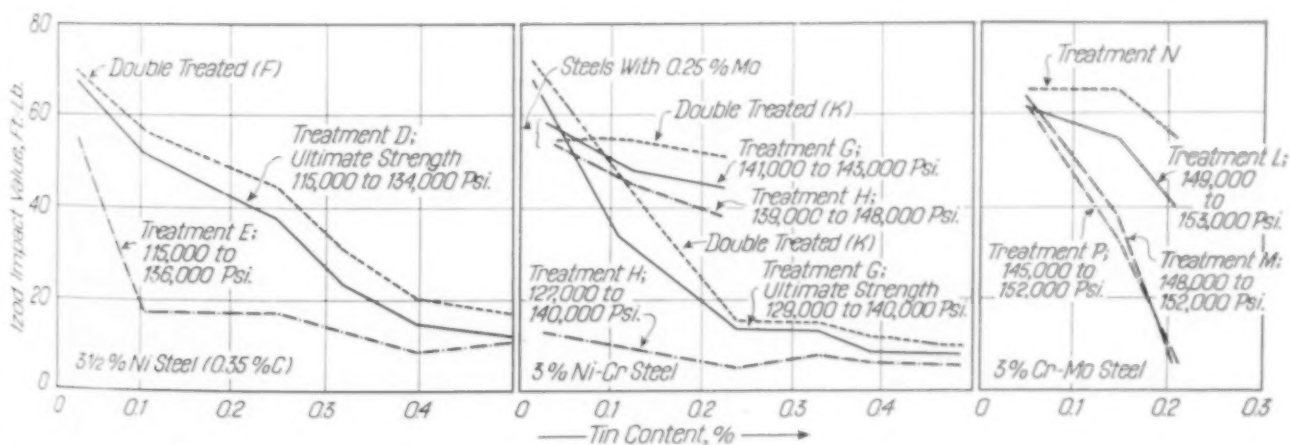


Fig. 3, 4 and 5 — Influence of Tin on Oil Hardening Alloy Steels. Treatment D is oil quench from 1525° F., temper at 1110° F. and oil quench. Treatment E is same, except furnace cool from tempering heat. Treatment F is E followed by a second tempering at 1110° F. and oil quench. Treatments G, H and K are respectively D, E and F, except that tempering temperature

is 1165° F. Treatment L is oil quench from 1650° F., temper at 1150° F. and oil quench. Treatment M is same except furnace cool after tempering. Treatment N is the same as M but followed by a second tempering at 1150° F. and an oil quench. Treatment P is the same as L but followed by pseudo-nitriding: Reheating at 930° F. for 72 hr. and furnace cool

WEDGE-DRAW VS. TENSION TEST TO DETERMINE DRAWABILITY

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LACK of applicability of standard physical tests as criteria for estimating drawing formability has been mentioned briefly in the preceding sections of these articles on the wedge-draw test (METAL PROGRESS for May, June and July). As the practice of considering comparative values of tensile elongation between two metals as a measure of their relative formability is not uncommon, it will be of interest to examine the tensile elongations of a few aluminum alloys of known drawability. These alloys are listed in order of decreasing drawability in the table herewith, as expressed by the ratio r/R taken from Table I of the article in May. The illustration in the present article

shows the cross-grain wedges, drawn from these alloys, at reductions corresponding to the upper range of failure as determined by the experiments described in former installments. A number of cups drawn to the upper limit of their failure range are also shown for comparison. The wide difference in drawability between 24S-O and 24S-T is at once apparent by the comparison of the lengths of their respective wedges or the depths of the two corresponding cups.

Although the correlation between the wedge-draw test and actual drawability of the various aluminum alloys is good (as shown in the engraving in this article and in Table I of Part I—page 666 of May METAL PROGRESS) it is apparent that the tensile elongation as measured over a 2-in. gage length is of little value for predicting the drawability of any of these aluminum alloys. For example, the elongation in 2 in. for 24S-O and 24S-T is substantially

the same, although they are at opposite ends of the drawability range. Again, in the middle range of formability, it has been found that the alloys in Group 3 have very nearly the same drawability in a single operation*; yet in this

*Re-drawing might further affect the relationship of these four groups. So far the wedge-draw die has not been used for re-drawing operations.

Per Cent Elongation e_o of Various Aluminum Alloys (a)

ORDER OF FORMABILITY BY DRAWING	ALLOY	TENSILE ELONGATION			LIMITING r/R RATIO FOR CUP
		2-IN. GAGE LENGTH (TYPICAL)	¼-IN. GAGE LENGTH (TYPICAL)	0.01-IN. GAGE LENGTH (CHARACTERISTIC)	
1	24S-O alclad	20%	37%	65%	0.49
2	52S-O	25	37	80	0.50
3	24S-W alclad	23	—	—	—
	53S-W	22	30	65	0.52
	61S-W	22	30	70	0.55
4	52S-½H	10	20	70	0.54
	24S-T alclad	18	32	45	0.73

(a) Per cent elongation $e_o = \frac{\Delta L \times 100}{L_o}$ (where L_o = original gage length)



Series of Wedge-Draw Tests at Reductions Drawn in One Operation, Showing Good
Near Upper Limit for Failure and Cups Correlation Between Test and Performance

Identification of Samples

THICKNESS	ALLOY	$r \div R$	DIRECTION OF "GRAIN"
Cups, left to right			
0.032	24 S-T	0.70	
0.032	24 S-T	0.70	
—	61 S-W	0.55	
—	53 S-W	0.52	
0.051	24 S-O	0.49	
Wedge-draw coupons, left to right			
0.032	24 S-T	0.70	Across
0.032	24 S-T	0.70	Across
0.040	52 S- $\frac{1}{2}$ H	0.61	Across
0.040	61 S-W	0.61	Across
0.040	53 S-W	0.61	Across
0.032	24 S-W	0.58	With
0.040	52 S-O	0.55	Across
0.51	24 S-O	0.51	With


group the elongation on 2 in. for 52S- $\frac{1}{2}$ H is less than half the value of the elongation for the other alloys in this group. It can also be seen that the elongation in $\frac{1}{4}$ -in. gage length does not correlate with drawing formability.

It was first thought that the deformations in simple tension as measured over a 0.01-in. gage length nearest the break might be the true ultimate deformation inherent within the material. However, in the case of 24S-O, deformations have been obtained during drawing operations considerably above the maximum ever measured in 0.01-in. gage lengths on the standard tension coupon. Conversely, in the case of pure drawing of 24S-T, shear failure always occurs at deformations lower than those indicated by the 0.01-in. deformation values of the tensile test. The elongation in 0.01 in. varies greatly along the break in the tensile coupon, since this value is determined by the orientation of the particular grain over which the measurement was taken, and for this reason a number of tensile coupons are measured adjacent to the crack and a characteristic value of the elongation in 0.01 in. has been selected and shown in the table. However, it must be pointed out that this value

of elongation does not have the validity of "typical" data, which implies its derivation from a large group of statistical data.

These results prove clearly that the tension test values of elongation give but little insight into the magnitude of the deformations that the metal is capable of withstanding without rupture under drawing operations. This is not surprising because, as explained in the earlier articles of this series, the

stress relationships in the two processes are completely different. The stress in the tensile coupon varies from a uni-axial tension stress in the straight portion of the coupon to tri-axial tension stress in the neck of the coupon at the moment before failure. During the drawing operation, on the other hand, combined compression and tension stresses are always present in a relationship that is most favorable to large plastic deformations without failure.

It is believed that the wedge-draw test develops stresses closely similar in magnitude and relationship to those developed during the drawing process (while the tension test does not) and is, therefore, a practical means of evaluating drawability of alloys now used in aircraft construction. 

STATUS OF STEEL EXPANSION PROGRAM

Extracts of Report
By W. A. Hauck
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Steel Plant Facilities, W.P.B.

METAL PROGRESS, since early in 1941, has printed much information about the supply of metals reasonably to be expected — not the least of which is steel. Despite the position of America as the world's leading producer, it early became apparent that there would not be enough for defense preparations and aggressive war efforts *plus* normal civilian consumption, and only recently has official Washington adopted the view that there would be a lack even after civilians had been denied. Consequently on May 15, A. I. HENDERSON, director of the materials division of War Production Board, ordered an analysis of all projects authorized and underway, looking toward an expansion of the steel industry, to determine which of them should be pushed to completion as rapidly as possible, and which either deferred or abandoned as interfering with the production of military end products during 1942 and the first six months of 1943.

The situation in this complex problem of steel capacity as of late fall 1941 was given in METAL PROGRESS for December. On page 918 of that issue it was noted that the Supply Priorities and Allocations Board on Sept. 30, 1941 had approved the recommendation of W. A. HAUCK, now chief of the planning unit for steel plant facilities, W.P.B., that the following enlargements to the then existing capacities be made:

Coke	9,359,000 net tons
Pig iron	13,810,550
Openhearth ingots	8,744,000
Electric ingots	2,018,000

As a result of the recent study ordered by Mr. HENDERSON, Mr. HAUCK now recommends that

about one-fifth of the authorized coke and pig iron expansion be deferred or abandoned, and about one-eighth of the openhearth capacity.

Completion of the recommended program will present this picture of the nation's steel-making capacity in net tons:

	DECEMBER 31, 1941	JUNE 30, 1943
Pig iron	59,406,410	70,351,410
Ingots		
Electric	3,741,310	5,759,310
Bessemer	6,721,400	6,721,400
Openhearth	78,107,260	85,799,260
Total ingots	88,569,970	98,279,970

The increase in openhearth steel capacity will be obtained in three ways. New furnaces will provide 4,891,000 tons, hot metal from blast furnaces instead of cold scrap in the charge will account for a gain of 2,163,000 tons, and restoring and enlarging old furnaces will bring in 638,000 tons—a total of 7,692,000 tons increase by June 30, 1943 as now recommended.

Mr. HAUCK tabulated the projects, and of the total increase in ingot capacity, 5,165,000 tons will be completed in 1942 and the additional 4,545,000 tons brought into production in the first six months of 1943. Many of the projects are well on their way to completion at present and some already are in operation.

No such increase in steel ingot facilities can be undertaken without a corresponding increase in pig iron capacity. In fact, the report calls for an even larger increase in raw materials facilities to make up for the reduced amount of purchased scrap expected next year and thereafter. Thus the expansion program actually starts with the expansion of iron ore mining in New York, New Jersey, Texas, southern California and Utah.

A further step in this program is the construction of 21 new ore boats for the Great Lakes which.

in addition to present capacity, are expected to fill ore needs through 1944 and thereafter.

The increase in pig iron capacity is to be brought about by six expedients:

From 20 new blast furnaces	8,118,000 tons
From 6 abandoned furnaces restored	1,235,000
From enlargement of 9 existing furnaces	853,000
From use of sintered ore	599,000
From use of thinner furnace linings	140,000
	<hr/> 10,945,000 tons

Some details of the pig iron program were given in "Critical Points" in last month's METAL PROGRESS. Completion of the pig iron program will make a total capacity of 70,351,410 tons available; deducting 9,500,000 tons necessary for merchant iron and ferro-alloys leaves 60,851,410 tons available for steel making.

Full use of the entire 98 million tons of ingot steel capacity will require 109,463,223 tons of metallic charge, made up as follows:

Pig iron	60,851,410 tons
Plant scrap	26,828,607
Metal in ore	5,834,400
Purchased scrap	16,000,000

These sources provide a bare surplus of only 51,194 tons, and only if the purchased scrap reaches 16,000,000 (a figure that may be too high to achieve). The report therefore recommends that additional pig iron capacity be constructed to insure against declines in the purchasable scrap.

Text of Report (in Part)

Definite steel requirements for the entire war program have always been difficult to obtain and for the most part were incomplete and misleading, due to lack of necessary detail and constant revision, mostly upward. Various estimates have been received on over-all requirements for steel which could not, however, safely be considered as any more than a partial guide on the necessary ingot capacity. Total steel requirements, present and future, for the entire war program by specific products and tonnages have not been fully established. On certain products, however, such as plates, current and near future requirements have been closely determined but even on this emphasized product, it is not possible to safely predict future requirements as the basis for establishing any further needed plate capacity.

Basic capacity of the steel industry is measured in terms of ingot tons which include open-hearth, electric furnace, and bessemer ingot capacities and is definitely known as of certain dates. Total mill finishing capacity is also known but the capacity of these mills by specific

products is flexible and depends on demand and the type of such products.

In the absence of definite product requirements, it became necessary to establish a plan for increasing basic capacity and providing balancing facilities in a plant where the war demand for its various products was in excess of the capacity of the industry to adequately supply and it appeared clear that this condition would probably continue. To a considerable extent, the projects for increasing capacity originated under this plan, after exhaustive studies were made on the possibility of providing such capacity in other logical areas from existing facilities. In numerous cases, such as the aircraft, ship, and tank programs, it was obvious from the start that additional capacity would be needed to help meet the constantly increasing steel requirements and it was so provided.

It is well known that openhearth steel ingots are made principally from pig iron and iron and steel scrap. Due to the present and prospective acute scrap shortage, it became necessary to build additional blast furnaces for increasing production of pig iron to offset this growing shortage of scrap. This was done in order to secure highest possible production from existing ingot capacity. To service the ingot capacity of 88,569,970 tons as of Dec. 31, 1941, it became necessary on account of this scrap shortage to provide 3,000,000 tons of extra pig iron capacity to insure so far as possible full future production from this existing ingot capacity, based on an estimated annual supply of 16,000,000 tons (estimate may be too high) of purchased iron and steel scrap. This 3,000,000 tons of extra pig iron capacity is part of the 10,945,000 tons of new pig iron capacity provided in this curtailed expansion program.*

The plan of providing extra pig iron to offset iron and steel scrap shortage and balance ingot capacity requires coke ovens and blast furnaces much in excess of the number necessary, could dependence be placed on a future normal supply of scrap.

The requirements and supply of metallics for the expanded capacity are barely in balance. This is a dangerous situation in view of the declining supply of scrap. More pig iron capacity is essential to better insure maximum production from the existing ingot capacity.

Included in this expansion program are

*EDITOR'S NOTE: The details published last month, page 83, indicate that the net gain in pig iron capacity during 1942 will be 3,180,350 net tons.

additional blooming mills, semi-finishing mills and finishing mills. These mills not only provide finishing capacity necessary for utilization of new ingot capacity, but often provide a better balance for existing capacity. In some cases it was also necessary to provide additional ingot capacity for better balancing maximum finishing capacity for certain products.

Also included in the program are 2,200,000 tons of new basic openhearth ingot capacity sponsored by the Navy Department (45% of the 4,891,000 tons of total additional capacity of new openhearth furnaces included in this expansion program). Also included are 361,000 tons of additional new electric furnace capacity likewise specifically sponsored or installed by the War and Navy Departments.

Originally the objective of this steel expansion program was to provide adequate steel capacity to meet, as needed, direct and indirect war requirements for the Army, Navy, Maritime Commission and Lend-Lease. It was also intended at that time to provide for essential civilian demand.

In the earlier days of the defense program there was considerable steel production for civilian consumption. Such production has since been gradually eliminated. At the present time only a small restricted tonnage is provided for so-called civilian use and an analysis of the end products from such tonnage discloses direct connection with the war program.

In further consideration of the objective for steel expansion, it is as difficult and unsatisfactory as ever to predict definitely future demands for steel for the war program and any additional capacity needed. Steel demands for the war program are now in excess of supply. In the meantime, it is advisable to rush completion on all steel projects herein recommended as most urgent and susceptible to earliest completion and secure the maximum benefit in the shortest possible time.

In planning the steel expansion program, consideration was first given to installing new capacity in existing plants. This method has the advantages of earlier start of production, less steel and other scarce materials consumed in construction, lower cost, more efficient operation and better economic value after the war. Difficulties experienced in financing expansion under this method with public funds somewhat restricted its general application.

In certain cases it was necessary to establish entirely new plants in order to decentralize


the industry and establish construction near consuming areas as well as to make full use of adequate reserves of suitable raw materials, especially iron ore in areas other than the Great Lakes ore area. Instances of this are the Columbia Steel (U. S. Steel Corp.) project near Provo, Utah, the Sheffield Steel project at Houston, Tex., and the Kaiser project at Fontana in southern California. The Republic Steel project at Chicago is a similar instance. Plants of this type are known as "grass root" plants.

Reopening Old Plants

Considerable additional ingot capacity as well as pig iron capacity, coke capacity and mill capacity was secured through the rehabilitation of shut-down and practically abandoned facilities. 1,235,000 tons of additional pig iron capacity have been secured through the restoration of abandoned blast furnaces, 853,000 tons secured through enlargement of existing blast furnaces, 599,000 tons secured to date (more to follow) through the use of sintered ore and 140,000 tons secured by the use of thinner linings. These projects account for 2,827,000 tons of the additional blast furnace capacity included in this expansion program and the critical materials used were comparatively little and far under such requirements for new blast furnaces.

638,000 tons additional openhearth capacity were secured through restoring or enlarging existing furnaces, also using comparatively little critical and scarce materials.

Of special interest is the 2,163,000 tons of additional ingot capacity secured in existing openhearth furnaces by the use of hot metal from the additional pig iron capacity being provided in this program. This 2,163,000 tons of additional capacity did not require new openhearth construction and accordingly no critical or scarce materials were used.

At the present time every effort is being made to avoid, to the greatest extent consistent with practicability, the use of critical and scarce materials in the completion of the construction program now underway, and projects are now stripped of such materials. This conservation of critical and scarce materials is in accordance with the policy adopted by the War and Navy Departments and is the subject of special instructions to the steel industry. This should eliminate much tonnage of critical and scarce materials with a consequent saving of this tonnage for military end products. 

SECONDARY COPPER FOR BEARINGS,

WAR WORK &

ALLOY STEEL

By Advisory Committee to W.P.B.
National Academy of Sciences
(Draft by Ernest E. Thum)

THE INDUSTRIES which collect, reclaim and use secondary copper have been seriously disrupted from their accustomed ways; the primary aim of this report was to suggest ways and means whereby the maximum amount of metal can be guided into its best, quickest and most economical use, without debasement of grade.

The first installment, published in *METAL PROGRESS* for June (page 819), reviewed the statistics, to get an idea of the size of the problem. In the period 1935 to 1940, both years inclusive, 2,857,100 tons of secondary copper was recovered as metal and in alloys, of which 2,092,400 tons was absorbed by remelters, non-ferrous manufacturers and foundries.

In the second installment (July issue, page 66) it was shown that the manufacture of composition ingot by remelters was doubling in volume at the end of 1941, when it was on the order of 300,000 tons ingot annually, and the demand is primarily for analyses with low impurity limits (Army and Navy specifications) at the very time when there is no outlet for low grade ingot into normal civilian channels, when the sources of clean, old scrap are drying up, and when good plant scrap must—by Government order—be returned to the originator of the raw material. To meet the immediate demands, enough unalloyed copper plant scrap and No. 1 demolition copper must be made available to ingot remelters to enable them to meet the demands of high priority castings to be made in the non-ferrous foundries.

This 300,000 tons of alloy ingot, containing

approximately 200,000 tons of copper, is now being used almost exclusively for priority materials. A recent study indicates its ultimate destination. Important fractions are contained in yellow brass ingots, in bearings and bushings, and in bronzes with low impurities.

Proceeding to a consideration of these main classes, demands for yellow brass were then analyzed. An accumulation of at least 100,000 tons a year of "orphan" high zinc brass was anticipated, denied to civilian consumption and unwanted by the war industries. To this must be added a sizable amount of even more impure metal which has been sent to smelters under the terms of "conversion contracts", now prohibited. Reclamation of high zinc brass into alloy bronze ingot of analyses desired by the armed forces involves dilution with three times its weight of low zinc alloy, and obviously is an impracticable method of utilization. Another outlet is smelting and separation into its components; the difficult smelting problem was discussed briefly, and it was recommended that the processes and available capacity be appraised, with the view of reclaiming the copper, zinc, tin and lead in this surplus brass as separate metals of commercial purity.

Other important outlets for secondary copper will now be discussed.

Bearings and Bushings

Two general families of alloys are widely used in bushings and bearings for all sorts of machinery, large and small. One family is represented by "gun metal" or Navy Composition G (88-10-2 copper-tin-zinc, low in lead) and the other is high leaded tin bronze (80-10-10 copper-tin-lead). (Leaded copper—or "lead bronze"

containing more than 20% lead—is used by the Navy, and in the automotive and air engine industries.) A typical bearing plant would ordinarily finish both 88-10-2 and 80-10-10 in the same machine line, and experience indicates that a certain admixture of turnings and shop scrap is inevitable. This normal contamination means that machine scrap from the manufacture of 88-10-2 bearings, bought under most naval, aircraft, and ordnance contracts and now specified at 0.30% lead maximum, and of course held at a comfortable margin below that maximum, would be mixed with enough turnings of higher lead material so that the remelted scrap would analyze more than 0.30% lead, too high for re-use as 88-10-2 in Navy Composition G. It would be necessary to charge a considerable proportion of lead-free copper and tin to remelt this scrap into ingot to meet the original specification. (Of course, a large proportion of a bearing foundry's own scrap can be segregated, remelted immediately and satisfactorily, as each pattern has distinctive sizes and shapes of sprues, gates and risers.)

Committee B-5 of the American Society for Testing Materials has questioned the desirability of imposing such low lead as is currently demanded by aircraft and naval specifications for bushings, valve guides and bearings. This low lead specification in naval specifications is probably a heritage from the old gun metal when it was not used for bearings at all, but handed down year after year long after guns were made of steel. Aircraft specifications have always been pretty tight "on general principles"; in other words, aircraft engineers didn't know whether a little lead would hurt the bearing or not, so they just kept the lead out. Generally speaking, lead is a desirable anti-friction metal; note the widely used 80 copper, 10 tin and 10 lead; also the lead babbitts, and also the lead-copper alloys. Unfortunately no tests for standards of performance are in accepted use, and it is common knowledge among metallurgists in the industry that one consumer will specify a low lead bearing for a certain machine whereas another consumer will accept a high lead alloy for the identical service.

After a study of some 28 current specifications now in use, a sub-group of A.S.T.M. Committee B-5 appointed for the purpose finds that they fall within three groups of alloys which typically are as follows: Copper 88, tin 10, zinc 2 (gun metal); copper 88, tin 8, zinc 4 (a "straddle" alloy); and copper 80, tin 10, lead 10. There

is good engineering backing for the suggestion that all of these could be consolidated and standardized on no more than two alloys for bronze bearings, with somewhat wider impurity limits, as follows:

	88-10-2	LEADED BRONZE
Copper	86 to 89%	77 to 81%
Tin	7½ to 11	9 to 11
Lead	1.0 max.	8 to 11
Zinc	1½ to 4½	1.00 max.
Iron	0.25 max.	0.25 max.
Nickel	0.75 max.	0.50 max.
Phosphorus	0.05 max.	0.50 max.
Antimony	..	0.35 max.
Other elements	..	0.35
Tensile strength	40,000 psi.	28,000 psi.
Elongation	20%	8%

In addition to the evident desirability of standardizing on a very few alloys, rather than a multitude of non-interchangeable variants, it will be observed that this recommended analysis of 88-10-2 for bearings contains up to 1.00% lead in place of the present limit of 0.30%.

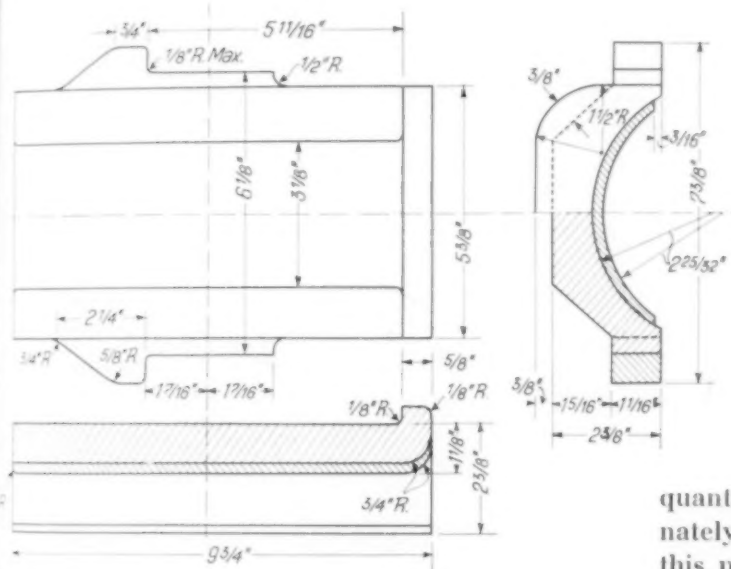
It may be questioned whether such a move would merely postpone the evil day. Obviously, if a bearing alloy contains nearly 1% lead and is further contaminated with turnings of leaded bronze with 10% lead, it will be impossible to remelt the contaminated turnings directly into specification ingot containing less than 1% lead. The relief will come by way of the larger amount of scrap readily available that contains substantially less than the new 1.0% lead limit, but somewhat more than the old 0.30% limit. Likewise a campaign to save the scrap will result in better segregation and less contamination.

At present the problem of supply is serious. It is said that the finished weight of an aircraft bearing (a large item in present business) is only one third of the rough casting; two thirds is reduced to turnings. (The original ingot was melted from virgin metal.) Because of plant contamination, it takes a good deal more lead-free metal to remelt these turnings into the original specification, with the result that 2½ to 4 lb. of virgin metal is required for every pound of metal shipped as bearings. Obviously such a practice, if continued, would rapidly lock up in process a mass of alloy ingot that would have to be worked off elsewhere.

To conclude: The revised specifications for bearing alloys for civilian use will undoubtedly be acceptable. Since the major use, however, will be for war service it is recommended that revised governmental standards be given careful consideration.

Railroad Bearings

A very considerable amount of secondary copper ingot (and some virgin metal) is absorbed annually in bearings for railroad rolling stock. The total amount of copper-lead-tin alloy locked up in existing engines, passenger train equipment, and freight cars is on the order of 250,000 tons. The railroad industry must feel that a sizable portion of this is dispensable, for the Mechanical Division of the Association of American Railroads has a special committee now studying suitable substitutes for their massive bronze-backed journal bearings, and has already accepted designs that reduce the weight of a bearing about 8% and also has reduced the copper analysis from 78% max. to 70% max. There is, of course, a reluctance to



1920 Standard Journal Bearing of American Railway Asso., Mechanical Division. Minimum thickness for backs is $\frac{1}{8}$ in., and for linings is $\frac{1}{4}$ in.

some tin and zinc. The so-called 5½ by 10-in. bearing, shown in the adjoining sketch, might be regarded as the average size for American freight cars, and contains about 25 lb. of bronze. It is lined centrally with about ¼ in. of a lead babbitt, which lining extends upward on the outer end in order to resist sideways sway of car and axle. Many bearings are replaced because of wear on these flanged ends.

New bearings are made either by the railroads themselves, or by numerous foundries of two principal companies, namely, the Magnus Metal Corp., Chicago, and National Bearing Metals Corp., St. Louis, Mo. Ordinarily this work is done on a toll basis; namely, the railroad delivers worn bearings and receives new ones in return for which it pays a certain price per pound. In reclaiming the material, the babbitt lining is first "sweated" off at a low temperature, and then the bronze is melted, sweetened with 2 or 3% of new metal, and recast.

Information is lacking on how much secondary metal is required to replace that worn and lost in these remelted car bearings. (Most of the wear comes on the babbitt lining rather than the bronze backing.) Perhaps it was on the order of 10,000 tons in 1941. It is metal dissipated, yet is necessary merely to keep the present cars rolling, and unless railroad bearings be changed fundamentally in design and maintenance, is a quantity of metal that must be supplied. Fortunately, railroads will accept scrap material for this purpose that would be difficult to market elsewhere. Very few freight cars have mechanical bearings (roller or ball).

American railroads have 46,000 passenger and Pullman cars; about one quarter of them have three-axle trucks. All but about 5000 of them use the same type of bearings as freight cars use; ball and roller bearings are used on the others, and in fact are standard on all high speed equipment. Designs of mechanical bearings are interchangeable with plain bearings—that is to say, they can be installed in existing cars without changing the trucks.

Interstate Commerce Commission figures for 1939 show that the American railroads owned 45,200 locomotives. Most of these run on large, thick-walled bronzes; a modern steam engine requires 3500 lb. of such material, and at least one important engine builder which made 650 engines in 1940 and 1200 in 1941

change any piece of essential equipment that has a century of use behind it, especially since some experiments with iron-backed (instead of bronze-backed) bearings were so unsatisfactory that such a bearing is barred under "Interchange Rule No. 19" from cars acceptable for interchange from one railroad to another at junction points. Nevertheless, the plea of "emergency", and "indispensable transportation" should not be used to prevent changes, if such changes will cause no traffic delays and conserve scarce metals.

The standard freight car bearing is an arch-shaped block of bronze containing generally 70% copper and the balance mostly lead with

utilizes virgin metal in the bearing foundry. Some ten years of successful experience with mechanical bearings on steam locomotives have resulted in equipping, by a single bearing company, some 830 locomotives with 7550 bearings on driver axles. More than half of these (65%) are replacement bearings, that is, put into existing locomotives and are interchangeable with the original plain bearings. New diesel locomotives all are equipped with mechanical bearings.

Any large car-building and engine-building program will absorb a correspondingly large amount of secondary ingot or purchased scrap for bearings. 65,000 new freight cars were put into service during January to October, inclusive, 1941. W. H. S. STEVENS, assistant director of the Bureau of Statistics, Interstate Commerce Commission, says it is his understanding that the future program calls for 900 locomotives and 150,000 freight cars. The number of locomotives is less than actually built in 1941 but on this basis, there will be required for bearings:

900 locomotives @ 3500 lb. bronze	1,570 tons
150,000 cars @ 200 lb.	15,000

a total of approximately 16,500 tons of bronze. To this must be added somewhere around 10,000 tons for replenishing worn bearings; the demands of the railroads will be on the order of 25,000 tons of bronze in 1942.

In view of the undoubted ability of the mechanical bearing to give superior service in engines and passenger equipment, and of the relative stagnation of the mechanical bearing industry, now that its principal customer, the passenger automobile industry, is denied it, it is recommended:

(a) That consideration be given to the plan of equipping new and newly converted passenger cars exclusively with mechanical bearings.

(b) That mechanical bearings be applied, where feasible, to engines and tenders, both new and old, to the existing capacity of the roller and ball bearing industry.

(c) That the use of virgin ingot (copper, tin and lead) be restricted for engine and car bearings of the conventional heavy wall type, thus encouraging the use of secondary copper high in lead.

(d) That an insistent and rapid effort be made by a joint conference of competent engineers in the railroad, bearing and automotive industry, to design and study in service a bearing requiring no change in existing boxes wherein the major portion of the bronze back is replaced by a malleable iron casting or other material, more available than a 70% copper bronze.

The desirability of recommendation (d) is evident in order that we may be prepared for any emergency. As already noted, the American railroads now have locked up in their 1,820,000 freight cars, 46,000 passenger cars, and 45,000 locomotives no less than 250,000 tons of bearing bronze. Based on experience in other industries, at least three-quarters of this is dispensable (replaceable by iron or steel) and recoverable. Based on the A.R.A. standard analysis, this "sink" of metal contains:

Lead	15 to 22%	or	34,000 tons
Tin	5 to 7%	or	11,000 tons
Copper	77 to 68%	or	135,000 tons

This should properly be considered as an emergency reserve of metal, rather than a place to dump unwanted alloy ingot. It is obviously too important a resource of the very strategic tin to be smelted in a wasteful way. Fortunately, electrolytic methods are available either for recovering high purity tin from such material, or for electrodepositing the lead and tin together, thus making electrolytic solder. In fact, plants for efficient recovery of the constituent metals are now in existence, but at present largely idle. (The 11,000 tons of tin mentioned above, if recovered as solder, would avoid the use of *any* new tin in this important commodity for such an entire year as 1937.)

This iron or steel-backed bearing suggested herein is no new device. Copper-lead alloys with $\frac{1}{32}$ to $\frac{1}{16}$ -in. wall have been standard for solid bearings on automobile transmissions and differentials, and a leading manufacturer has for several years been promoting the use of steel-backed bearings in this service, thus saving from 65 to 80% of the copper, depending on original thickness of the copper alloy. About two thirds of this company's very large output has now been successfully converted, and with entire satisfaction. Its chief metallurgist says that very few indeed are the industrial bearings (now ranging from $\frac{1}{8}$ to $\frac{3}{4}$ in. wall thickness) that could not be replaced with $\frac{1}{16}$ in. of bronze on a steel backing, and give superior service. On this basis there is enough bronze in one ordinary railroad bearing to make at least four bearings of the iron-backed type.

Castings for the War Effort

Gun Metal — Statistics, as well as common knowledge, show that an increasing amount of secondary copper (alloy ingot from remelters) is going into castings for Army ordnance, naval

vessels, transport, and aircraft engines, as well as into the auxiliary war effort, power plants, powder plants and chemical factories. Rigorous specifications are enforced for these parts, notably valves and fittings, and only by careful grading of raw material, together with admixture at times of virgin metal, can the present analyses be met.

The problem of maintaining chemical purity in alloy ingots made from secondary metal has already been outlined in the remarks above about bronze bearings of 88-10-2 analysis. This is the well-known Navy G specification (gun metal) whose chemical requirements are 88 copper, 10 tin, 2 zinc with 0.30% lead max. This alloy — together with a modified G metal containing 88% Cu, 8% Sn, 4% Zn — is now much used in big naval castings and cast assemblies where doubtless only a small part of the whole really needs the low-lead metal. The Non-Ferrous Ingot Metal Institute's 88-10-2 equivalent (Ingot 2B) permits up to 1% lead. A leading producer's test records on thousands of bars and over years of production show that the low lead G metal and the 1% lead 2B ingot are indistinguishable as far as physical tests made on cold bars are concerned. However it may well be that, as the temperature of service goes up beyond 550° F. (the ordinary limit for "steam bronze" or "valve bronze" in which the Navy permits 2% lead),

the low limits on lead (0.30%) are desirable. Since the price spread between Navy G and Remelt Ingot 2B is 1½¢ per lb., and the former requires No. 1 copper for dilution purposes, it is recommended that all governmental agencies scrutinize their current drawings and orders and revise the requirements so as to permit 88-8-4 containing 1% lead in all parts where the low lead is not clearly demanded.

Ounce Metal — Another alloy much used for medium pressure parts, small pumps and for general service is "ounce metal", the leaded red brass known as 85-5-5-5. Ingot melters use, as a principal raw material for this composition, "bronze" bearings and "red brass" scrap. Generally, such scrap runs higher in lead and lower in tin, with the result that the remelters have established a Grade 4B of 83 copper, 4 tin, 6 lead and 7 zinc. It is thus midway between 85-5-5-5 and the specification 81-3-7-9 ordinarily known as "valve composition" and recognized in Air Corps, Army, Navy and Federal specifications. Some say that Grade 4B is somewhat inferior to 85-5-5-5; others say that the two are equally good; at any rate, it would serve excellently for many of the services now using 85-5-5-5, made only by using some virgin tin. Here again, the desirability for scrutinizing drawings and specifications is indicated.

Aluminum bronze is increasingly used by

Huge Manganese Bronze Propeller, in Rough Ground Condition, at Cramp Brass & Iron Foundries Division of Baldwin Locomotive Works. Propellers for Liberty ships are 18½ ft. in diameter and weigh 11¼ tons; a tanker takes a 19½-ft. propeller weighing 18 tons



the aircraft engine industry. It is not nearly so easily handled as other common copper alloys, and the chemical compositions are more sharply limited. A typical specification for ingot metal requires 89% copper, 1% iron and 10% aluminum, no more than 0.05% lead, and 0.30% of all other materials. It is seen that this alloy contains a lot of aluminum, which is specified as "none" in most brasses and tin bronzes, and also that it has very small tolerance for lead which is the omnipresent metal in other reclaimed ingot. Scrap handling, classification, separation, and melting are therefore almost too much for the ordinary remelter except in quarantined departments, and the problem of raw material supply is especially serious. Nevertheless, the principal foundries depend on alloy ingot for at least two reasons: The alloy, even if made of virgin metal, must be pigged and analyzed before remelting for casting, and equipment for this cannot well be spared in a busy foundry. Likewise, melting in large furnaces, as possessed by ingot remelters, gives much larger quantities of uniform metal and greatly reduces the necessary analytical work.

No recommendation is made as to aluminum bronze; it is cited as an important alloy whose production requires important amounts of low impurity secondary if the use of virgin metal is to be avoided.

The conclusion of this too-brief survey of the war demands indicates that raw material is the principal problem of the ingot remelter. This is no new problem to them, but is currently intensified by the great demand for compositions low in what they know as "normal" impurities, and by the restrictions on shipments to civilian industries which normally absorb the less pure materials readily available. Two requirements are indicated:

(a) More intensive study by competent civilian and governmental metallurgists to determine whether emergency alternate specifications cannot be instituted for many parts now requiring unnecessarily high grade metal.

(b) Allocation of sufficient No. 1 copper scrap to remelters to sweeten their melts and produce the low-impurity alloys *really* necessary.

Copper as Alloy in Iron and Steel

It is proper to discuss this topic, since a surprisingly large amount of copper is used as an alloying element, and apparently it has not yet figured in the statistics for secondary copper. American Bureau of Metal Statistics (1931-1940)

reports tonnages of new unalloyed copper going into "copper-bearing steel" ranging from 800 tons in 1932 to 4600 tons in 1937. The total consumed is considerably higher, for J. E. JACKSON, metallurgical engineer for Copper Iron & Steel Development Association, estimated that 18,100 tons were contained in the copper irons and steels made in 1940, with 24,300 tons expected in 1941. This does not mean that this much copper was used up, for circulating scrap iron and steel now contains about 0.15% of residual copper. Nevertheless, much copper was consumed, and no matter where it came from, whether refined electrolytic metal, plant scrap, or demolition scrap, this copper is permanently locked up in the iron and removed from our available stock of copper. The situation therefore warrants scrutiny.

Up to a relatively few years ago copper was looked upon as a deleterious element, and many metallurgical troubles were blamed upon its presence. (This was often a convenient alibi, for copper could always be found when looked for, in fractional percentages, due to its omnipresence in the Appalachian iron ores.) During the last 20 years, however, its use in low carbon steels, to about 0.25%, has been well established, being responsible for a worth-while improvement in corrosion resistance to normal atmospheric exposure, and in "tooth" for conventional coatings. More recently, many laboratory studies have been made on the alloying effect of copper in steel, and it has been authoritatively asserted that it improves the yield point of low and medium carbon steel (structural variety) without increasing hardenability and without thereby decreasing weldability. Hence we find a tendency for copper to be placed in most of the high yield strength structural steels promoted by the various steel companies, not only for its effect on the physical properties, but also to improve the corrosion resistance to atmospheric exposure, and thus permit thinner than usual gages (it permits the designer to reduce the allowance for rusting).

It has also been demonstrated that copper from 0.75 to 1.5% is a valuable element in increasing the strength and hardness after proper heat treatment, and even further improvement by the process of precipitation hardening. This is a commercial practice in the steel casting industry—especially by certain foundries which make heavy castings for excavating machinery. As an addition to gray iron it is said to be (*Cont. on page 252*)

STANDARD DRAWING DIES (CARBIDE)

FOR SMALL

AMMUNITION

By Earl Glen
Sales Engineer
Carboloy Co., Inc., Detroit

A PRIME REASON for the rapidly increasing use of carbide dies for cartridge case production—from the smallest to the largest calibers—is their greater resistance to wear. This reduces the down-time for die changes (thereby increasing output), reduces the number of die reconditionings required, and reduces the total number of dies required for a given output. In addition to this, of course, the decreased wear of dies of the carbide type insures greater uniformity of product.

While this article relates primarily to the production of brass cases with carbide dies (and for the purpose the word "dies" will be used for "carbide dies"), indications are that dies of the same basic design can be used equally successfully on substitute materials, including steel.

Experience has demonstrated that, to keep production going, the ratio of dies required is only one carbide in place of 20 of toolsteel. Thus, 200 carboloy dies will take care of a plant that normally would require 4000 steel dies for the same continuity and quantity of output. This will be true when their selection takes into consideration the possibilities of re-working worn dies for earlier operations.

In addition to the decidedly lower initial cost of tools for a given production, carbide dies also have demonstrated a marked advan-

tage from the standpoint of operating costs. This is largely due to decreased maintenance, and less delay in production for die changes. There are not only fewer dies to take care of, but they do not have to be reconditioned as frequently. Today, it is common to get 1,000,000 pieces per die change, against an average of 50,000 when using steel dies. (Production up to 4,500,000 pieces has been reported before service is needed.) Tapering and shouldering dies, experience has shown, last almost indefinitely when made of cemented carbide.

So far, carbide dies have been used largely in sizes interchangeable with toolsteel dies, dimensions having been based on the latter to facilitate substitution. Doubtless with rapidly growing use it will become desirable to design the press equipment, recesses, and production sequence so as to achieve the optimum benefit of the improved dies. One of the obvious points to be considered is that die recesses in presses should preferably be larger. Dies of toolsteel are large enough to carry the stresses of operation, but in carbide dies, this wall thickness is reduced by the amount cut out for the carbide nib, and the case (really, the nib holder) is thus slightly weaker.

The advantages of a larger die recess for a larger die shoe or holder would include the ability to provide (a) greater support for the carbide nib, and (b) an increase in nib dimensions and a greater reserve of material for re-finishing to larger work when worn.

Changing Over to Carbides

When starting to use carbide dies it would probably be best to secure them in finished form for the original set-up. From the standpoint of continuous operation, minimum cost, and avoidance of delays, however, plants should thereafter provide as rapidly as possible their own facilities for servicing, finishing and re-working. Rough-cored dies can then be purchased and finished in the buyer's tool room, thus reducing further the original die costs and stock requirements to the very minimum. This practice has been followed for years in wire drawing mills and is now an established procedure throughout that industry.

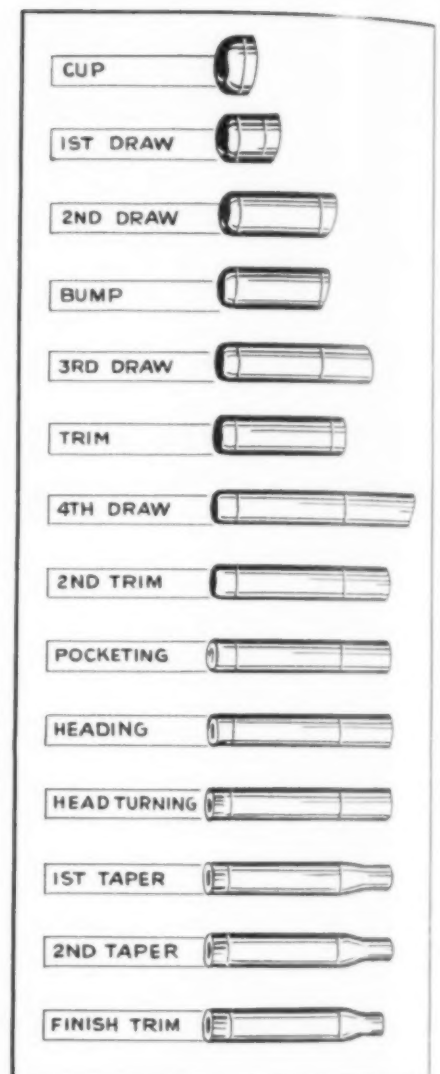
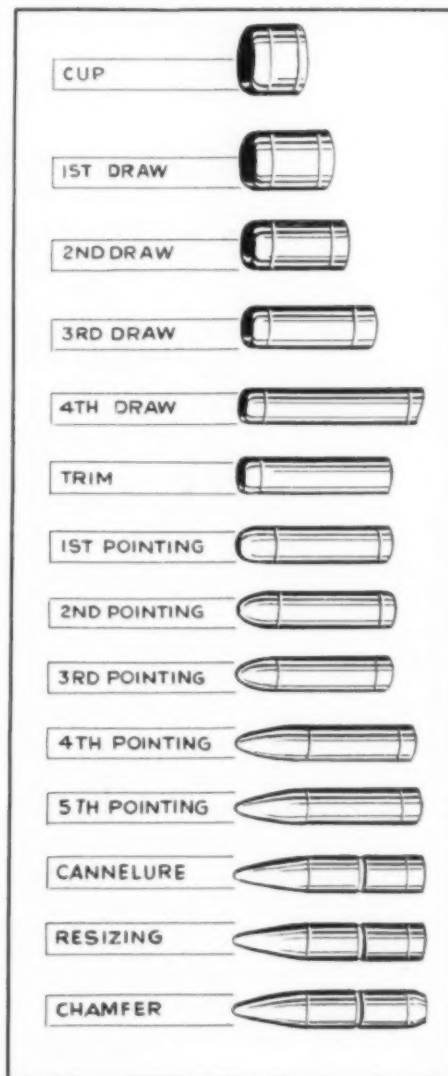
Grinding, lapping, and general re-working technique has been simplified and improved. It is now possible to maintain carbide dies just as easily as the toolsteel varieties. In this connection, the Carboloy Co. has for some time provided assistance to users in training service men both at our own and in their own plants. As to service equipment, all that is really required is standard tool room speed lathes, flexible shafts and diamond tools for boring. Some shops prefer to use a selection of diamond splints for pliers for turning ID's of the die nibs.

General Production Sequence

Irrespective of whether carbide or steel dies are used, manufacturers with deep drawing experience would have no major difficulties in setting up to draw brass cartridge cases.

Basic operations required for production of 30-caliber and 50-caliber cartridge cases consist of: Blanking and cupping, four drawing operations, three trimming operations, two indenting and heading, two tapering and shouldering (combined, usually), one form turning, one mouth chamfering, one drilling or punching for vent at

Schedule of Operations for Satisfactory Manufacture of Bullet Sheath (Left) and Cartridge Case (Right)



bottom of pocket or indentation, and a marking operation. The above sketch gives a workable sequence.

After cupping and after each draw (or double-draw) the case is annealed to remove the work hardening effect, and before the next draw the case must be pickled to remove oxides acquired during the softening anneal, followed by immersion in rinsing baths, soaping, and a final hot rinse.

Blanking and Cupping

Current practice is divided about evenly as to whether or not the blanking and cupping operations are performed by the

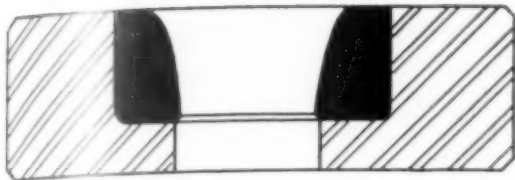


Fig. 1 — Carbide Nib in a Steel Shoe — a Carbide Die — Suitable for a Heavy Single Draw, as in Cupping the Brass Disk

brass mill or by the cartridge case producer. By far the better procedure is to have these operations — particularly the blanking — performed in the plant that casts and rolls the brass, in order that the large amount of scrap may be most expeditiously handled. Normally it is also advantageous to produce cups rather than disks, since blanking and cupping can be combined in the same operation. Sometimes, the cupping die forms part of a two-piece die assembly in a double action press, the upper half of the die obviously being for blanking. For blanking the disk out of the brass strip toolsteel is now preferably used.

Where disks are purchased by the cartridge case producer, the cupping can be performed in a die of the general shape shown in Fig. 1.

Drawing Dies

The established practice today is to use four draws to convert a cup into a 30-caliber or 50-caliber cartridge case or bullet jacket. Where press equipment permits, each drawing operation is usually performed in pairs, using a long punch and two dies — an upper and a lower one — the latter being self-aligning and usually of semi-floating construction. In this way carbide dies for

annealing and cleaning the cup it is generally better to use a single die with one heavy reduction rather than a double die with two more moderate reductions in succession. In fact

some manufacturers eliminate one die in the second press also, making this a single reduction operation — particularly in drawing 50-caliber cases. Carbide dies lend themselves somewhat better to these single draws than toolsteel dies, since they maintain their shape longer under the much more severe pressure. To some extent, the die assembly depends on the press equipment available, but usually where there is a sufficient length of press stroke, dies are assembled in pairs — two carbide dies replacing the usual double-reduction steel die — one above the other.

Dies for this type of work are shown in Fig. 2. Figure 3 shows the type of dies used for the first

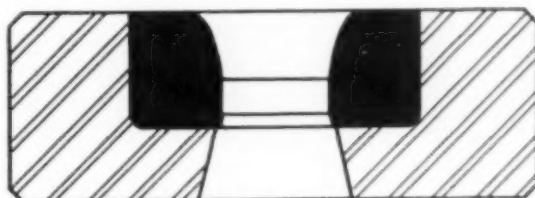


Fig. 2 (above) — Dies for Intermediate Drawing Operations, Especially When the Draw Is Performed in a Single Stroke Through a Pair of Dies, One Above Another. Fig. 3 (below) — shouldering and tapering dies



Fig. 4 — Solid Carbide Die for Form Drawing of Primer Caps



Simplified Master List of Drawing Dies for Small Ammunition

PART	DRAW No.	CASE OR SHOE		NIB		ROUGH BEARING, LENGTH	FINISHED BEARING, DIAM.
		DIAM.	HEIGHT	DIAM.	HEIGHT		
30-cal. a. p. jackets	All 4	1.995	0.500	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	0.305 to 0.496
30-cal. t. & b. jackets	All 3	1.995	0.500	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{16}$	0.305 to 0.422
30-cal. jacket	Size & re-size	1.110	0.432	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	0.306
30-cal. cartridge case	All	1.727	0.625	1	$\frac{1}{2}$	$\frac{3}{16}$	0.4605 to 0.655
50-cal. a. p. & tracer jacket	1 & 2	2.245	0.625	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	0.649 to 0.870
	3 & 4	1.727	0.625	1.000	$\frac{1}{2}$	$\frac{3}{16}$	0.505 to 0.638
50-cal. cartridge case	1 & 2	2.740	0.937	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{16}$	0.913 & 0.996
	Others	2.370	0.625	1%	$\frac{1}{2}$	$\frac{3}{16}$	0.793 to 0.880

and second operations respectively in shouldering and tapering cartridge cases after they have been drawn to cylindrical shape, and Fig. 4 shows a solid carbide die used for form drawing of primer caps.

Recommended Die Sizes

The figures in the table on page 231 represent the results of a major effort on the part of carbide die producers to simplify the production, maintenance, and procurement problems for cartridge case manufacturers. The primary step in this simplification of dies, whose dimensions formerly ran all over the lot, was to group the ones for consecutive operations so as to be able to re-use worn dies by a simple re-cutting process which may be carried out in the plant's tool room.

Thus, it will be noted, only a single basic external size is now required for all draws on jackets for 30-caliber armor piercing shot, tracer bullets and ordinary "balls". At the outset, of course, it would be necessary to secure a group of such dies to finish to proper inside dimensions. To simplify this problem, the rough cored hole of this particular basic die is available in a series of stepped diameters, thus reducing the amount of re-cutting necessary.

After initial set-up it is usually necessary only to purchase dies for the last draws on the jacket (smallest ID), since the dies which they replace can be re-cut (enlarged) to take care of the earlier draws on the jacket.

Similarly, for the 50-caliber jackets, two basic die sizes will take care of top and bottom dies for all draws. For the 30-caliber cartridge case, one basic nib and case or shoe size again takes care of all draws, and of both top and bottom dies where these are used in tandem. In addition, 30-caliber cartridge case dies are now interchangeable with the third and fourth draws of 50-caliber jackets. This gives them an even greater re-cutting value, and cuts down the tool room stock. (In this case there is a slight difference in the approach angles between dies for different draws, and the rough cored dies may be secured with these variations in angles for the initial set-up. The variation is sufficiently slight, how-

ever, so that when a fourth-draw die is re-cut to a third-draw size, the correction can be easily made in the refinishing operation.)

For the 50-caliber cartridge case, two basic die sizes are required, the die for the first and second draws having a somewhat larger over-all diameter and height than those used for subsequent draws. One advantage of this scheme is that the larger case or shoe provides additional strength for the initial reductions, when taken through a single die, as compared to the use of upper and lower dies in tandem for each of the third and fourth draws.

One point might well be mentioned: With carbide dies it is preferable to use a mechanical stripper, although some manufacturers strip with the dies on the reverse stroke — as is common practice with steel dies. In the latter case, the back edge of the die must be kept in good condition; otherwise the work will not strip properly from the punch and may damage the tools. If the bottom die is used for stripping, a reverse taper of two to three tenths in the bearing is desirable. As an additional precaution, some users provide a stripping edge on the die as well as a mechanical stripper.


As to drawing compounds, there are practically as many opinions as there are producers of cartridge cases. Not only are numerous types of compounds used, but the manner in which they are applied and diluted also varies. Some, for instance, dilute soluble oil 40 to 1; others to a thick emulsion. Some flood the dies and work while others control the amount on both the ID of the die and OD of the work by the use of felt wipers.

Lifting a Die Nib, Freshly Pressed From Powder, From Its Mold — a Preliminary Step to Sintering and Finishing. Photo by Van Fisher



BITS AND PIECES

Metallurgicus' Own Page

AS ANNOUNCED last month, this page is for odds and ends of laboratory practice or improved plant operations that would otherwise go unrecorded. Share your kinks with other ASMembers! Authors of items will receive any one of the  books other than the Handbook, as they choose, for their trouble.

Case Depth Required for Accurate Hardness Readings

How thick does the carburized case have to be to give Rockwell readings truly indicative of the hardness? Here are a few test results that may be of interest:

Samples of S.A.E. X-1020 carburized in liquid carburizing bath, followed by water quenching, tested as follows:

CARBURIZING		CASE DEPTH	ROCKWELL A OBSERVED	ROCKWELL C EQUIVALENT	ROCKWELL C OBSERVED
TIME	TEMPERATURE				
45 min.	1700° F.	0.014 in.	76 to 78	55	41
60 min.	1635	0.014	80 to 82	59	43 to 45
60 min.	1700	0.017	80 to 82	59	60
75 min.	1635	0.016	82 to 84	62	59
90 min.	1700	0.022	83 to 84½	63	63

METALLURGICUS

[EDITOR's dumb question: What is the meaning of the term "case depth" and how do you measure it?]

Quenching Powdered Metal

In some X-ray diffraction studies we could not quench powdered steels (—120 mesh) into completely austenitic structures although small lumps of the same metal can be so retained. All the steels had about 1.7% carbon; one had 2% chromium, another 2½% manganese, and the third 2% nickel and 1% chromium. Perhaps it is inherently impossible to obtain complete austenite retention with fine powders of this composition. The small particle size with large free surface could allow the volume change of the martensite reaction to be more easily accom-

modated, and so the reaction is made more possible than in the lump.

This indicates a point to be taken into consideration in the application of powder methods to the investigation of states of metastability. The ordinary grain size effect would not explain the result, since the particle size corresponds to what is considered quite a coarse grain size in steels. (N. J. PETCH, Cavendish Laboratory, Cambridge, England.)

Measuring Moisture in "Bone Dry" Hydrogen

The amount of moisture in gases dried to a dew point of —40° F. is so small that the method of measuring it by noting the appearance of moisture on a refrigerated mirror of known temperature is quite inaccurate. However, minute traces of moisture or oxygen in purified

hydrogen can be noted accurately by a two-element electron tube. In it a steady flow of electrons pass from hot tungsten filament to the plate. When the sample of hydrogen passing through this tube is pure, all the electrons reach the plate. Oxygen or water molecules, however, pick up electrons, form negative ions,

and reduce the electron current. The change is easily measured and can operate appropriate warnings or controls. (PHILIP R. KALISCHER, metallurgist, Westinghouse Research Laboratory, East Pittsburgh.)

Improving the Notched-Bar Test

Among numerous factors affecting notched-bar tests is the timing of the heat treatment—whether before or after the sample is prepared. I recall some published tests on a chromium-copper steel, tested at —100° C., which gave values of 5 ft-lb. if notched *after* heat treatment, but consistently around 100 ft-lb. if notched *before* heat treatment.

A second point is that tempering after normalizing sometimes improves the notched-

bar test figures (keyhole notch *after* heat treatment). Note the following tests on plate material of regular S.A.E. 4340 analysis:

	NORMALIZED AT 1650° F.	NORMALIZED AND TEMPERED AT 1050° F.
Tensile strength	150,000 psi.	123,000 psi.
Yield strength (0.01% offset)	75,000	90,000
Brinell hardness	311	248
Charpy keyhole test at 78° F.	8 to 10 ft-lb.	22 ft-lb.

Varying the tempering temperature from 1000 to 1300° F. did not change the figures in the last column much. Tests on a normalized steel of quite similar analysis but containing 0.15% vanadium, both in plate form and as forged, were substantially unchanged after tempering. (M. A. SCHEIL, director of metallurgical research, A. O. Smith Corp., Milwaukee.)

Spot Test for Moly Steel

If you want a quick test to separate 18-4-1 high speed from moly high speed, or even to spot molybdenum alloy steels containing 0.20 to 0.25% Mo, do it this way:

1. Place a small piece of filter paper on a clean section of the metal.
2. Place 3 drops of 1-1 HNO₃ on the filter paper, and after a few seconds transfer the paper to a test tube.
3. Add 1 ml. of perchloric acid, shake for a few seconds and add 10 ml. distilled water.
4. Add 1 drop of sodium sulphocyanate solution,* shake until the red color becomes uniform.
5. Add 8 drops of stannous chloride,† shake several seconds until the solution becomes colorless. (Add 1 or 2 more drops if necessary to kill the red color.)
6. Add 10 drops of NaSCN solution.

If the sample is a molybdenum high speed steel a bright orange color develops, which turns to a bright red in 15 min.

A steel containing a smaller amount of molybdenum causes the solution to turn to a light orange.

If less than 0.20% molybdenum is present in the steel, the solution remains colorless. (RAYMOND TOWNSEND, chief chemist, Jones & Lamson Machine Co., Springfield, Vt.)

*50 g. NaSCN per liter.

†Dissolve 32 g. SnCl₂ in 40 ml. warm concentrated HCl, and dilute to 100 ml. with cold water.

EMBRITTLEMENT OF HIGH CHROMIUM IRONS

By G. Riedrich and F. Loib

Abstracted from *Archiv für das
Eisenhüttenwesen*, Oct. 1941, p. 15

HIGH chromium-iron alloys — say 16% Cr and over, low enough in carbon to have a ferritic microstructure at both low and high temperatures — tend toward large grain size, not refinable by heat treatment, with correspondingly low toughness as measured by the notched-bar test. F. M. BECKET, who first studied the alloys systematically, pointed out that when they contain more than 20% Cr the normal metal is reasonably tough at elevated temperature, but if cooled after extended stays at about 900° F. and tested at room temperature, its notched-bar value is very low. If such a brittle steel is reheated and tested while hot, the toughness is restored. The effect was called "900° brittleness". [See "The Book of Stainless Steels", pages 362 and 589.]

The effect was apparently not due to carbides, since high purity induction furnace alloys containing carbon as low as 0.006% with 24.35% of chromium exhibited "900° brittleness", as also did samples made from electrolytic alloys melted *in vacuo* and deoxidized with hydrogen. Neither was it due to the sigma phase, which only appeared when alloys contained 35% chromium.

The present authors have studied the phenomenon in 48 alloys made in a 12-lb. induction furnace, basic lined. The small ingots were forged and rolled to 0.079-in. strip, and then water quenched from 1375° F. Specimens were appraised by bending; in the foregoing condition *all* the 48 alloys could be bent 180° without cracking.

Aside from toughness, other physical properties measured are:

	WATER QUENCHED FROM 1375° F.	AFTER 1000 Hr. AT 900° F.
Specific gravity	7.62	7.64
Hardness	170	320
Coercive force (Oersteds)	3.2	5.2
Magnetic saturation (Gauss)	13,800	13,850
Resistivity	66x10 ⁻⁴	62.5x10 ⁻⁴
Lattice constant	2.897Å	2.897Å

A series was designed to show the influence of chromium in low carbon alloys, during long heating at various temperatures between 750 and 925° F. By increasing the time at temperature, alloys of progressively lower chromium content were embrittled, with the following limitations: (a) No embrittlement occurred in any of the alloys even after 1000 hr. at 1025° F.; (*Cont. on page 248*)

CORRESPONDENCE & FOREIGN LETTERS

"Stretch Point"

for extension-under-load measurements

COVENTRY, ENGLAND

To the Readers of METAL PROGRESS:

It is to be hoped that the article by GEORGE P. LENZ in February's METAL PROGRESS (and supplemental note on page 682 of the May issue) will meet with the attention it undoubtedly deserves. The various terms used in American literature making reference to the mechanical properties of materials are confusing, and any method of clarifying the position should be of considerable assistance to those who carry out specification tests and to those called upon to interpret the results.

In England we generally embody, in our specifications for tensile properties, limits for yield point or proof stress (at 0.1, 0.2, or 0.5% extension) although limit of proportionality may be given under certain circumstances. The term "yield stress" may be used in place of "yield point", and this is defined in British Standard Specification No. 18-1938 "as the stress at which a visible permanent increase occurs in the distance between gage points on the test piece observed when using dividers; or at which, when the load is increased at a moderately fast rate, there is a distinct drop of the testing machine lever, or in hydraulic machines a hesitation in the movement of the gage finger". A note is added that in general the "yield stress" applies to mild steel and wrought iron.

Proof stress is defined as "the stress which is just sufficient to produce a permanent elongation equal to a specified percentage of the original gage length". It can be determined by direct measurement of the gage length, after application and removal of the various loads to the test piece, or by the offset method described by Mr. LENZ. Other methods not given in this specification are the four-point method for the determination of approximate proof stress when maximum and minimum limits are specified,

and the three-point method for verification that the metal possesses the minimum proof stress.

It will be seen, therefore, that we do not use the term "yield strength" and it is interesting to observe that it has been omitted from the definitions and practices enumerated by Mr. LENZ in favor of the term "stretch point". Checking his proposals over, "proportional limit", "yield point" and "proof strength" agree with accepted British practice, while the term "stretch point" is self-explanatory and has the same definition as that of the U. S. Navy Department for "yield strength". For those materials on which it is difficult or impossible to determine either limit of proportionality or yield point this new specification value should be readily acceptable. My own opinion of the term yield strength is that its similarity to the terms yield point or yield stress has led to some confusion, and general acceptance of the term stretch point will clarify the position.

R. J. BROWN

Chemist and Metallurgist
Morris Motors, Ltd., Engines Branch

Increase Production by Raising Output per Man-Hour

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

Our greatest progress in the furtherance of our present war effort is not going to be by building more plant — which, in fact, has now been officially frowned upon — but by using more efficiently the plant we have. The greatest error we have made so far is that we think of production in terms of man-hours rather than in terms of what that man in that hour can do.

When we begin to increase the efficiency of our present operations it will be a very simple thing to double our present production with the same number of man-hours. We can, inside of another few months, double that again if the

efficient methods which the industrial geniuses know can be applied and are enthusiastically followed.

As an example of this, in the present building of ships $\frac{1}{8}$ and $\frac{5}{32}$ -in. electrodes are largely being used for welding. If these should be changed to $\frac{3}{16}$ and $\frac{1}{4}$ -in. the speed of welding would be more than doubled. The cost of the electrode also would be reduced, the production of electrode by the same number of man-hours would be increased, and the reliability of the joint would be increased.

The great problem we have is not more welders, more shipyards and more men, but more efficiency with what we now have. Man-hours alone will never beat the Axis, as we are seeing. The efficiency possible by the application of industrial genius will.

JAMES F. LINCOLN
President
The Lincoln Electric Co.

Recovery of Values From Mixed Stainless Steel Scrap and Waste

BROOKLYN, N. Y.

To the Readers of METAL PROGRESS:

The increasing emphasis that will continue to be put on "Save the Scrap" doubly applies to metals containing large proportions of the strategic metals chromium and nickel. In the larger shops this is sorted for remelting, but the number of alloys included in the "stainless steels" is so large that turnings and odds and ends, in large and small shops alike, continue to build up a store of metal of unknown composition and uncertain origin. There are also older accumulations that contain important quantities of stainless steel, but have been considered unsuitable for remelting even after a magnetic separation, except as small additions to large charges making lower alloy steels. There is also the problem of reworking grindings—until now a totally wasted material.

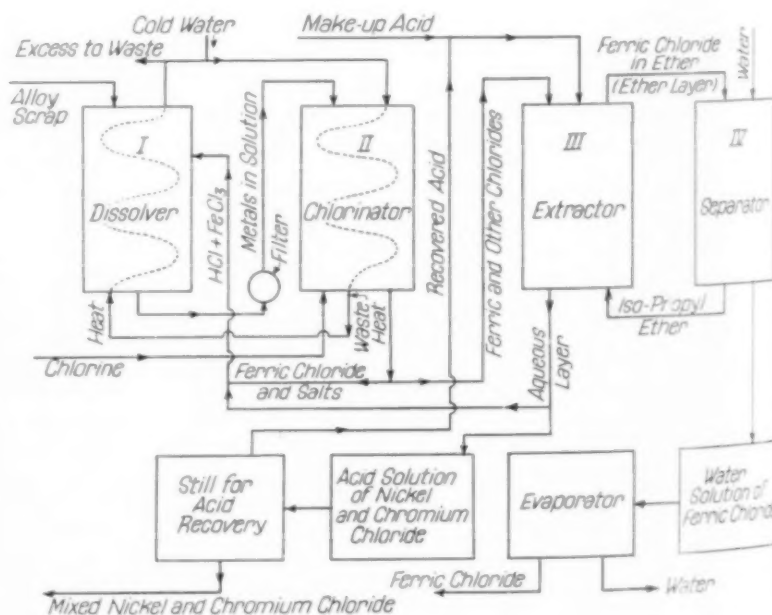
It occurred to the present writers that the chromium, nickel and iron might be separated chemically into useful products, and an interesting method was worked out with

the cooperation of the senior class in chemical engineering at Pratt Institute. Work was done on contaminated lathe turnings from a nearby small machine shop producing about 100 lb. of the waste weekly.

Production of nickel and chromium salts from scrap of this nature presents two obvious problems. The steel must first be dissolved—even though it is the nature of stainless steel to resist attack by ordinary reagents—and the relatively large amounts of iron must be removed completely and economically. These difficulties have been overcome in laboratory scale experiments, and a fairly pure mixture of nickel and chromium chlorides has been obtained. A flow sheet of the process as it might be conducted commercially is shown, in which the various steps are:

- I. The scrap is dissolved in a solution of ferric chloride, strongly acidified with hydrochloric acid.
- II. The solution is chlorinated to convert the ferrous chloride to ferric chloride.
- III. Ferric chloride is extracted from strong acid solution with iso-propyl ether.
- IV. The ferric chloride is extracted from the iso-propyl ether with water. (The ether is then recirculated with small loss.)

An acid solution of nickel and chromium chlorides is produced and from this the salts and hydrochloric acid may be recovered, the first for sale and the second for re-use. Ferric chloride can be recovered by evaporation, and is a marketable by-product.



Flow Sheet of Process for Converting Mixed Stainless Steel Scrap Into Iron, Nickel and Chromium Chlorides

In our work we were able to dissolve the original turnings (Stage I) more easily than expected. Part of the ferric chloride solvent is converted to ferrous chloride; exact control does not seem important, except that to avoid loss of acid an excess of ferric chloride is required. In general, the greater the acid and ferric chloride concentration and the higher the temperature, the more rapidly the scrap dissolved.

Stage II, regeneration of the ferric chloride with chlorine, is easy and rapid. This reaction is exothermic.

Stage III is the removal of ferric chloride from a portion of the chlorinated solution (part is sent back to the dissolver) with iso-propyl ether. More careful control is required in this stage; the acid strength must be around 20% HCl by weight, and good contact between the two liquid layers must be obtained. Under proper conditions ferric chloride was nearly completely separated. Part of the product (the aqueous layer) was recycled to Stage I to build up the concentration of nickel and chromium. The rest of the aqueous layer was distilled to recover most of its acid content. The residue is the end product, a mixture of crude nickel and chromium chlorides, usable as a source for dichromates and nickel plating salts.

In Stage IV the iso-propyl ether is stripped of ferric chloride by extraction with water, and recycled to Stage III. An interesting feature is that ferric chloride preferentially dissolves in iso-propyl ether in strongly acid solution; in solutions with low acid content the ferric chloride dissolves most readily in the water phase — really, a dilute acid.

Admittedly the process requires large quantities of chlorine — itself a restricted material — and could only be operated when the nickel and chromium to be recovered are more valuable than the chlorine required. It could only be operated successfully by someone experienced in the manufacture of hydrochloric acid, chlorine and ferric chloride. While ferric chloride is hard to handle, there are several materials available for containers such as pyrex glass, Dow's "Saran", acid resistant stoneware, carbon pipe and shapes and rubber-lined steel. We have taken no steps to patent this process, so it is available to anyone who is willing to spend (and possibly to lose) the money required for a pilot plant.

R. H. McCORMACK

G. F. KINNEY

Chemical Engineering Dept.
Pratt Institute

Ghost

I meant to do my work to-day —

But a brown bird sang in the apple-tree,

And a butterfly flitted across the field,

And all the leaves were calling me.

Poem by Richard le Gallienne



Butterfly eutectic in high alloy cast iron

CARL G. JOHNSON

Dept. of Mechanical Engineering
Worcester Polytechnic Institute

Anomalous Hardness of Welds in Low Alloy Steels

SHEFFIELD, ENGLAND

To the Readers of METAL PROGRESS:

The importance of welding in these days needs no comment; when coupled with the use of high strength, low alloy steels (in order to permit higher stresses and thus save weight) it introduces special problems which need careful consideration. One of the most important is bound up with the greater tendency of alloy steels, as compared with ordinary mild steel, to harden appreciably when air cooled from high temperatures. Such "air hardening" is especially effective in thin sheet, tubing, or other sections.

It is often thought that the relative tendencies of different steels to harden at welded joints may be measured by determining their hardness after air cooling from high temperatures, using samples of sheet of various thicknesses, thus determining the minimum thickness which can safely be used for a given steel without producing undue hardening. But certain low alloy steels, much used for welded constructions, may develop an appreciably higher

hardness when air cooled from *intermediate* temperatures, rather lower than those normally used for their heat treatment, than when similarly cooled from higher temperatures.

For example, consider the steel containing about 1.5% manganese and 0.25% molybdenum, frequently used for welding. Tests on steels of this type, cooled freely in the air from a series of temperatures rising from 650 to 850° C. (1200 to 1550° F.) have been reported by H. ALLSOP and H. BULL (*Transactions of the British Institute of Welding*, January 1942, p. 32). These tests show that peak hardness values were obtained at 725 to 750° C. (1330 to 1380° F.) — that is, in the temperature range somewhat above A_{c1} but well below A_{c3} . The actual value of the peak hardness for a given steel depended on the thickness of the material tested, being greater in ratio to the thinness of the sample, but in one set of tests on steel strips $\frac{1}{8}$ in. thick containing 0.32% carbon, 1.39% manganese and 0.35% molybdenum, the following values, expressed as Vickers diamond hardness numbers, were obtained after air cooling from the indicated temperatures:

675°	700°	725°	750°	775°	800°	825° C.
225	220	380	335	275	275	273

Similar peak hardness values were also found at actual welded joints which had not been subsequently heat treated. Thus, at a butt weld in a 16-gage tube, probably welded by the oxy-acetylene blowpipe, of steel containing 0.27% carbon, 0.55% manganese, 1.18% chromium and 0.25% molybdenum — another steel frequently used for welded constructions — a peak hardness value of 310 was obtained half an inch from the actual weld, the hardness value at the latter being 260. Although temperatures were not measured, it is highly probable that this peak hardness occurred where the steel reached a temperature somewhat above A_{c1} during welding.

It may be noted that the three alloying metals which these steels contained — chromium, manganese and molybdenum — all form carbides when they are added to steel, rather than enter into solid solution with the iron. It seems possible, therefore, that these peak hardness values, obtained on air cooling thin sections from temperatures just above A_{c1} , where

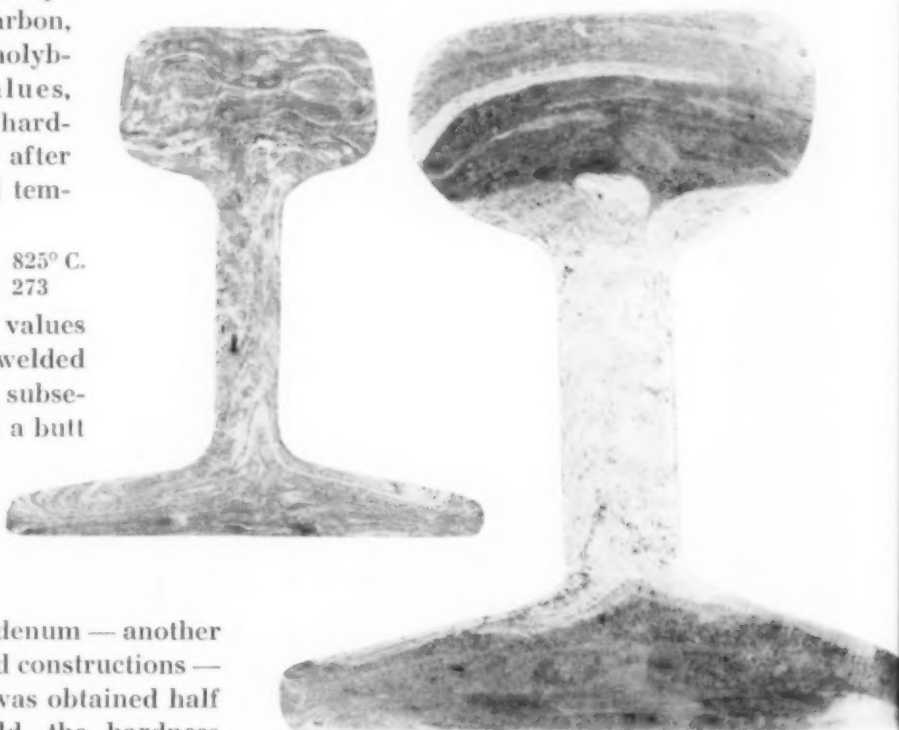
the structure of the hot steel consists of a mixture of austenite and ferrite, result from the major part (if not the whole) of these alloying metals being concentrated in the austenite which will thereby possess greater hardening capacity, at certain intermediate rates of cooling, than the less alloyed austenite which will exist in the same steel at higher temperatures at which the whole of the ferrite is in solution.

Whether or not this hypothesis be true, it is at least a fact that normalizing the welded article in the ordinary way, at a temperature somewhat above A_{c3} , not only refines the overheated zones — its principal function — but also removes effectively these hard bands.

J. H. G. MONYPENNY

Metallurgist

Brown, Bayley's Steel Works, Ltd.



Sulphur Prints of Wrought Iron Rails

Recently two curiosities were forwarded the Editor. The little print was made by C. M. NICHIE in the metallography course at Cornell. It is from a relic from his great grandfather who received it as a souvenir of the driving of the golden spike at the completion of the first transcontinental railroad (Ogden, Utah, April 1869). It is a 25-lb. section rail, of wrought

iron, and probably is the size and type used on the Central Pacific railroad when it was put through to the Coast. Today, it would be thought too small for a hand-car track in a stock yard!

The larger rail was recently picked up in the hills near Rolla, Mo., by CHARLES Y. CLAYTON, professor of metallurgy of Missouri School of Mines. It is rather heavy — about 60 lb. to the yard — which was the weight the Pennsylvania railroad was using on the Altoona hill for heaviest main line traffic at about the same time the Central Pacific was laying its 25-lb. section. In the middle '60's that road also used the first bessemer steel rails, 60-lb. section.

Improved Surface Condition of cast projectiles

UGINE, SAVOIE, FRANCE

To the Readers of METAL PROGRESS:

Casting into molds or ingots is an important and delicate operation often bringing into play opposing or incompatible conditions. For instance, agitation or turbulence in casting gives a fine and homogeneous structure, but it often has a bad effect on surface quality.

Now surface quality is extremely important in the further conversion into rolled and forged parts as well as direct use in castings. In the latter, poor surface quality increases the machining expense and number of rejects; in mechanical operations surface defects are intensified and much metal must be discarded. Surface acceptability depends further on the method of deformation; a piece which can be made by flat forging will permit surface defects which would be unacceptable in a piece which requires upsetting in the forging dies. Quality of surface required therefore depends on the form of the piece to be forged.

One of the most important types of surface defects is that which results from the turbulence or splashing of the liquid metal when it is poured. This causes premature solidification of drops of liquid metal thrown off during pouring on the cold walls of the mold; if this solidified metal is not remelted as the mold is filled by the liquid metal, it forms what is known as "cold shot". Cold shot may be extensive enough to form a crust which might be designated "cold plate" or "cold sheet".

The amount of splashing depends on the method of casting; whether or not the splashing is remelted when the mold is full depends on the metal and its casting temperature.

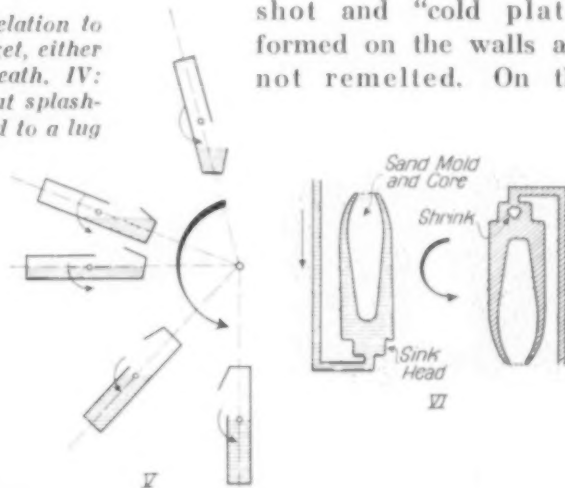
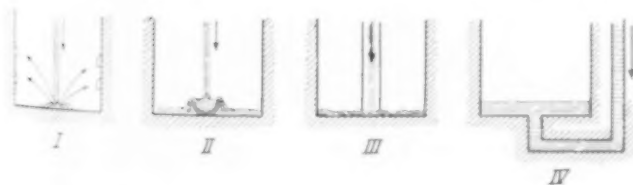
Confining the discussion to the casting of ingots, it may be noted that various devices have been tried to eliminate turbulence or premature splashing of the liquid metal on the cold walls.

Direct or top casting, while the cheapest and by far the commonest method, is very unfavorable since the impact of the liquid metal on the rigid bottom of the mold causes considerable splashing (Diagram I). This can be eliminated by placing diffusers at the point of impact in the form of a cup or bucket, or making a similar depression in the stool (Diagram II), or the vertical jet of liquid can be surrounded by a tube forming a sheath to guard against splashing (Diagram III).

The metal forming the tube or the cup should subsequently dissolve in the liquid metal, but this is rather difficult unless the cast is very hot. Thus, bottom pouring is often resorted to for mild steels of high melting point (Diagram IV); by retarding the rate of filling the mold, this method of casting has the further advantage of forcing the blowholes in unkilld steels further below the surface and thus diminishing the risk of scabby billets.

The extra mild, low carbon steels present the greatest difficulty in obtaining good surface for the reason that the shot and "cold plate" formed on the walls are not remelted. On the

Various Methods Used in the Pouring of Ingots and Their Relation to Splash. I: Top pouring is the worst offender. II: Cup or bucket, either separate or a depression in the stool. III: Protective tube sheath. IV: Bottom pouring. V: Durville method of direct casting without splashing. VI: Reverse method of casting shells so shrink is confined to a lug attached to the base



other hand, it is easier to get good surfaces with semi-hard steels or silicon steels. Furthermore, the re-incorporation of the cold shot in the molten metal can be prevented by a film of refractory oxide formed on the surface if the metal contains much aluminum.

With the quality of the surface depending thus on the type of steel, it can be seen from the foregoing that the choice of an economical analysis can be influenced by the form of the forged part and the method of forging, as well as the expected surface condition of the original ingot. Bottom casting, while commonly practiced in steel plants making large ingots for forging or plate manufacture, presents certain disadvantages. Notably it increases the depth of pipe with attendant risk of forming secondary pipe, as well as increasing the amount of return scrap comprising the runners and risers.

Recourse could be had to the Durville process of casting devised for the casting of aluminum and its alloys, and also (as noted by M. L. NORTHCOTT in METAL PROGRESS, July 1939, page 41) now being used for casting small ingots for toolsteels and quality steels. Diagram V shows the principle: The ladle and ingot mold are integral; originally the latter is upside-down, but on rotation, the mold is brought rightside-up and filled without agitation. It is direct casting without splashing.

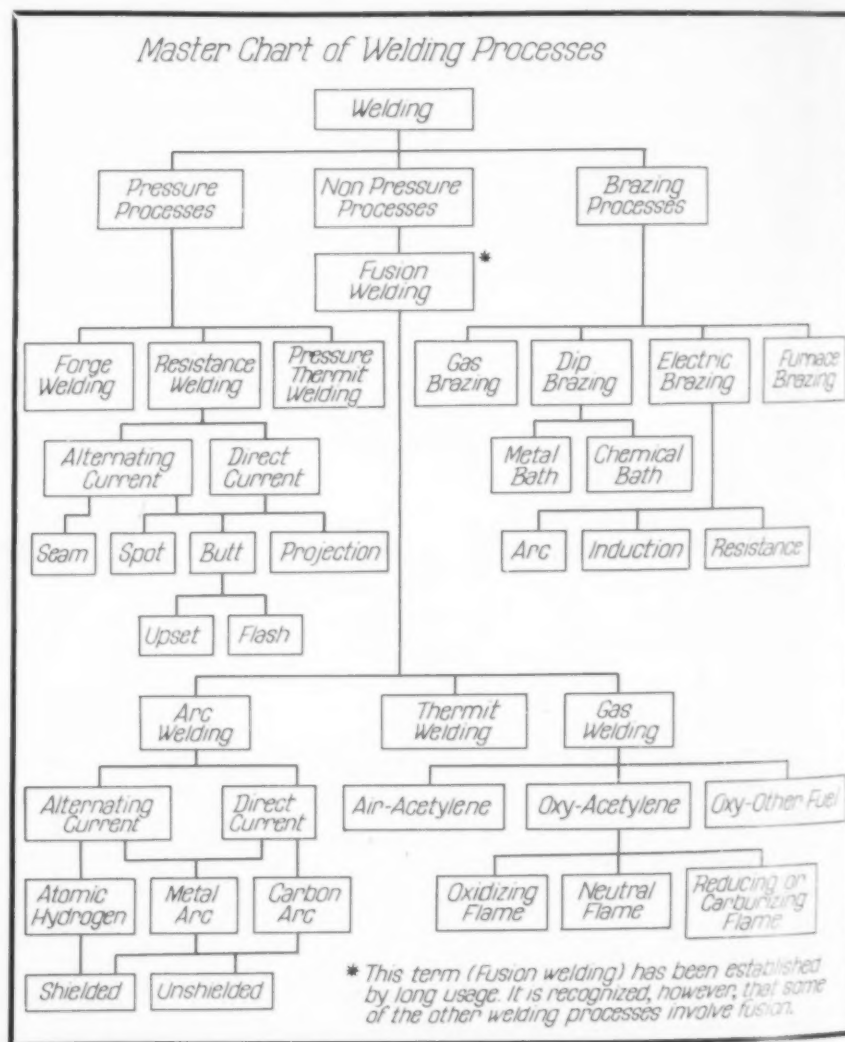
The reverse process, however, could also be used; with the shrinkage head placed initially in the bottom, the ingot could be bottom cast and then rotated. This gives the advantage of the good surface quality obtained by bottom casting and at the same time avoids the disadvantage of pipe by bringing the shrinkage head to the top during solidification (Diagram VI).

This process is particularly adaptable for hollow bodies, such as shells made

by casting instead of forging. Forging requires stronger material and becomes more expensive as the size increases; foundry difficulties, on the other hand, inversely decrease. However if cast shell are to be made without any forging, it is necessary to eliminate internal defects and at the same time obtain surfaces that are as perfect as possible, particularly on the interior cavity where machining difficulties are greatest.

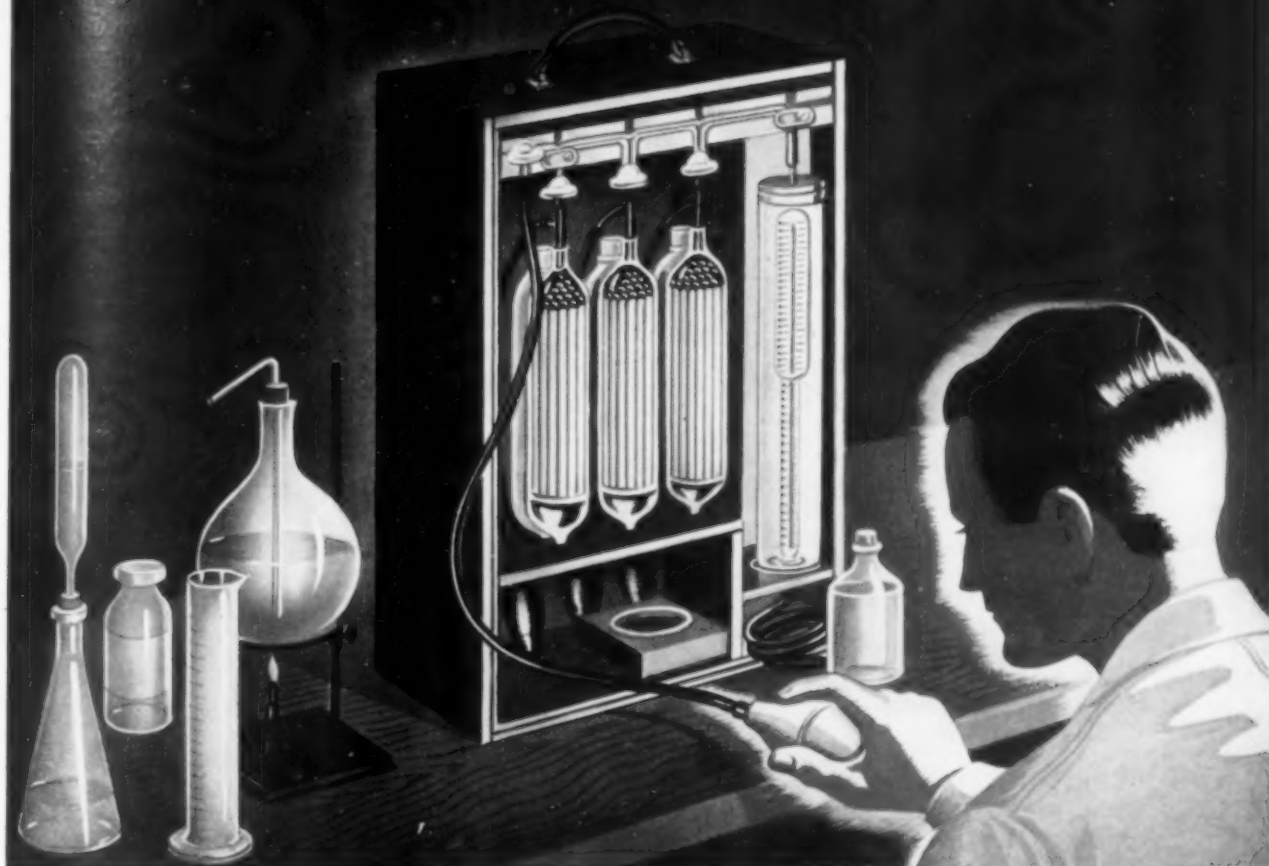
The two methods of fabrication can be combined by making cast-forged parts — casting the rough shape and giving it definite form by forging. It should be noted that the as-cast part must be the more perfect from the standpoint of compactness and surface quality, the less the machining tolerances. At the same time the foundry difficulties are greater because the walls are thinner and the cavity or hollow is larger and more restricted.

ALBERT M. PORTEVIN
Metallurgist and Consulting Engineer



Reproduced, by permission, from copyrighted pamphlet issued by American Welding Society entitled "Definitions of Welding Terms"

Hints for special atmosphere gas analyzers



Information supplied by "Metal Progress"

Analysis of special atmosphere compositions in heat treating furnaces, periodic or otherwise, is an excellent means of insuring consistent results. However, two precautions should always be observed in the interests of accuracy.

First; it should always be remembered that slow cooling of the furnace gases from operating to room temperature will cause reactions that alter the composition of the sample. The metal in the sampling tube may also affect the sample composition.

Speedy withdrawal of gas samples, followed by

instant cooling to room temperature by a cold water jacket around the sampling tube will minimize changes. In high temperature work, sampling tubes of material similar to that of the charge will be in better equilibrium with the furnace gases.

Second; when the Orsat method of analysis is used, analyses are on a "dry" basis. Separate tests, such as passing the gas over a dehydrating agent such as phosphorus pentoxide (P_2O_5), alumina (Al_2O_3), or lime (CaO) should be used to determine the presence of water vapor.

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PERSONALS

Bertrand S. Norris ☉ is now serving as metallurgist in the research laboratory, York Ice Machinery Corp., York, Pa.

Hans R. Stephan ☉ is now employed as assistant metallurgist at Allis-Chalmers Mfg. Co., Milwaukee.

Honored by a dinner commemorating the 50th anniversary of his association with the steel industry: William P. Woodside, founder member and past president ☉, vice-president, Climax Molybdenum Co. of Michigan, Detroit.

William Seymour ☉ is now metallurgist in the Works Laboratory of General Electric Co. in Bridgeport, Conn.

A. E. R. Peterka, executive engineer, manager of the Aircraft Products Division of the Lamson & Sessions Co., and chairman of the Cleveland Chapter ☉, has been ordered to active duty as a major in the Army Air Forces.

Harry J. Kligora ☉ has been transferred from the Farmingdale plant, Republic Aviation Corp., to the new Indiana plant as manager of sub-contracts division, Indiana Division.

Wilton F. Melhorn ☉, formerly upsetter shift foreman, drop forge department, Bethlehem Steel Co., Bethlehem, Pa., has been called to active duty as second lieutenant in the Office of the Chief of Ordnance, Washington, D. C.

Joseph Gray Jackson, assistant secretary, Philadelphia Chapter ☉, formerly patent attorney, Wm. Steell Jackson & Son, is now associate metallurgist, Production Planning Section, Artillery Division, Office of Chief of Ordnance, Washington, D. C.

Stephen D. Garst ☉, formerly assistant technical editor, American Foundrymen's Association, is now employed by the Socony-Vacuum Oil Co., East Chicago, Ind., as metallurgist.

Harold R. Wegner ☉, formerly metallurgist and plant superintendent, Syracuse Heat Treating Corp., is now metallurgist, Saginaw Steering Gear Division, Saginaw, Mich.

Frank K. Gardner ☉ is general superintendent, St. Catharines Steel Products, Ltd., St. Catharines, Ont.

Ralph E. Green ☉ has been transferred from Chicago to the Philadelphia office of Thwing Instrument Co.

Transferred: C. C. Edelen ☉ from district manager in Syracuse, N. Y. to the estimating department in the main office of Surface Combustion Corp. in Toledo, Ohio.

MEMORANDUM

To Production Executives:

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★ Before you make a Long Distance telephone call ★
★ today, ask yourself these questions: ★

★ 1. Is it necessary? ★

★ 2. Will it interfere with war calls? ★

★ The weight of war on the telephone lines is heavier ★
★ every day. We can't build the new lines to carry ★
★ it because sufficient materials aren't available. ★
★ We've got to make the most of the service we ★
★ now have. ★

★ Please give a clear track to the war effort by ★
★ confining your Long Distance calls to those that ★
★ are really necessary. ★

★ ★ ★ ★ ★ ★ ★ ★ ★ ★



**WAR CALLS
COME FIRST**

BELL TELEPHONE SYSTEM



PERSONALS

Lloyd B. Kramer Ⓔ, formerly with Union Drawn Steel Division, Republic Steel Corp. in Massillon, Ohio, is now metallurgist with Herman Machine and Tool Co., Tallmadge, Ohio.

Promoted: **Charles E. Spragg** Ⓔ to office manager in Hartford, Conn., for Jessop Steel Co.

Victor H. Lawrence Ⓔ, formerly assistant to the president of Otis Steel Co., has been appointed general superintendent of the Otis Works of Jones & Laughlin Steel Corp., Cleveland.

Promoted by Lindberg Engineering Co.: **Douglas B. Rader** Ⓔ, formerly designer and advertising consultant, to director of advertising; **Robert S. Aitchison** Ⓔ, to sales promotion manager.

David Shper Ⓔ, formerly openhearth metallurgist at the Inland Steel Co., has accepted a position as metallurgist in charge of heat treating in the armor plate division of the Maremont Automotive Products, Inc., Chicago.

Norman Kates, past chairman, Michigan College of Mining and Technology Chapter Ⓔ, is now metallurgist for the Accurate Steel Treating Co., Chicago.

William G. Van Note Ⓔ has been transferred from associate professor of chemical engineering to the mechanical engineering department of North Carolina State College of Agriculture and Engineering as associate professor of metallurgy.

Transferred: **Albert H. Graf, Jr.** Ⓔ, from the Cleveland plant of Ohio Crankshaft Co., to Atlanta, Ga., to take over the southern territory.

Raymond Ward Ⓔ, Campbell fellow in metallurgy at Columbia School of Mines, has been made research metallurgist for General Electric Co. in Pittsfield, Mass.

J. T. Phillips Ⓔ, formerly superintendent, Foster Wheeler Corp., is now manufacturing engineer for Aero Parts Mfg. Co., Inc., Wichita, Kans.

Edward L. Horne Ⓔ, formerly on the laboratory staff of the Duriron Co., is now materials engineer at the U. S. Army Air Corps Materiel Center, Wright Field, Dayton, Ohio.

E. I. Valyi Ⓔ has become associated with Lucius Pitkin, Inc., New York, consulting engineers, metallurgists and chemists.

John J. Fitzgibbon Ⓔ has resigned as foundry engineer of Whitehead Metal Products Co. to become metallurgist for R. Hoe & Co., Dunellen, N. J.

Maurice G. Jewett Ⓔ, formerly chief metallurgist and chief engineer of the Chain Division, Chain Belt Co., Milwaukee, is now in the Army as a lieutenant colonel.



Perfect Hardening Quicker from New Workers!

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Big parts and little—thick and thin—brass, steel, aluminum, magnesium . . . the products being inspected radiographically today are quite unlike one another. The facts to be determined also vary. Exposures are made with kilovoltages ranging from 5 to 1000 . . . and with gamma rays from radium. This means that there can be no one "standard" film. Three distinctively different types are needed—Kodak provides all three.

KODAK INDUSTRIAL X-RAY FILM, TYPE A

... primarily for light alloys

Has fine grain, high contrast, and is particularly suitable for low-voltage radiography of aluminum and magnesium . . . and million-volt radiography of steel.

KODAK INDUSTRIAL X-RAY FILM, TYPE F

... primarily for the radiography, with calcium tungstate screens, of heavy steel parts

Has the highest available speed and contrast when used with calcium tungstate intensifying screens. Also used for gamma radiography with lead-foil screens.

KODAK INDUSTRIAL X-RAY FILM, TYPE K

... primarily for the radiography, direct or with lead-foil screens, of lighter steel parts

Has the highest available speed in direct exposure . . . when used with lead-foil screens at higher voltages . . . and, for heavier parts, with gamma rays.

* * *

Kodak began its industrial radiographic research back in 1927, and the knowledge acquired in this experience may be helpful to you in your particular application. Write Eastman Kodak Company, X-ray Sales Division, Rochester, N. Y.

The new booklet "Kodak Products for Industrial Radiography" is available upon request.



PERSONALS

Transferred: **George I. Tull** is from Ordnance Department representative at Lycoming Division, the Aviation Corp., Williamsport, Pa., to chief inspector, Bethlehem Sub-Office, Philadelphia Ordnance District, with offices located at the Bethlehem Steel Co., Bethlehem, Pa.

Edward M. Schrock is on loan from his position as supervisor, statistical division, Jones & Laughlin Steel Corp., Aliquippa, Pa., and is a civilian employee of the Aberdeen Proving Ground as ordnance engineer dealing with problems of quality.

Edward M. Levy is now metallurgist, openhearth process control, Carnegie-Illinois Steel Corp., Gary Works.

A. L. Hodge, research metallurgist at Carnegie-Illinois Steel Corp.'s Gary Works, has been transferred to the U. S. Steel Corp. Research Laboratory at Kearny, N. J.

A. A. Gyoker has been called to active duty with the Ordnance Department at Watertown Arsenal as lieutenant in the heat treating section of the gun division.

Howard F. Bartels, formerly heat treater in the metallurgical laboratory, Illinois Tool Works, Elgin, Ill., has accepted a position as heat treater for Rock Island Arsenal, Rock Island, Ill.

Charles T. Flachborth is now in the engineering department of the General Electric Co., Schenectady, working on an assignment for the aeronautics and marine department.

Leon A. Jacobson has been transferred by the Army Ordnance Department to Richmond, Ind., as inspector in charge of the Richmond Works, International Harvester Co.

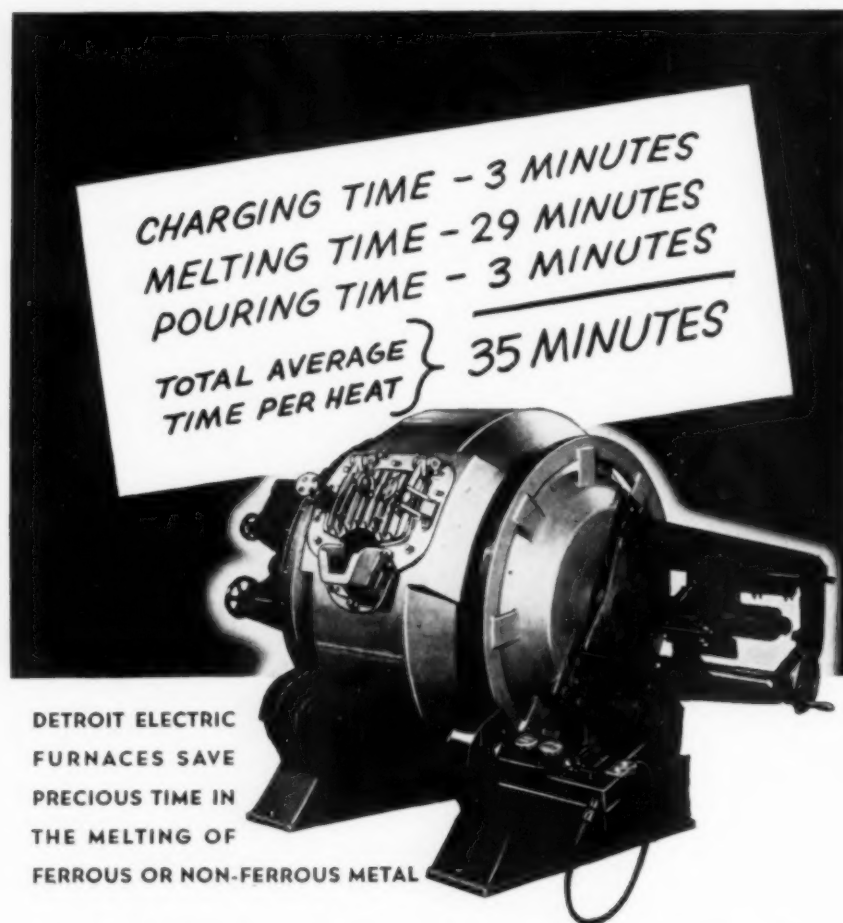
John Casey was graduated from University of Michigan with a degree in metallurgical engineering, and is now stationed at Wright Field as a second lieutenant connected with the metals unit of the Materiel Division.

Robert De Weese, B.S. in Metallurgical Engineering, Rensselaer Polytechnic Institute, is now working for American Steel & Wire Co., Worcester, Mass., as a technical apprentice.

Alfred F. Arand is now in the employ of the Rheem Mfg. Co. at the Houston, Texas plant.

S. R. Robinson, foundry metallurgist for Otis Steel Works of Jones & Laughlin Steel Corp., has resigned to accept a position as works manager for the Valley Steel Casting Co., Bay City, Mich.

Mario Cuniberti, Cornell University '42, is now employed at Wright Aeronautical Corp. in Paterson, N. J.



CHARGING TIME - 3 MINUTES
MELTING TIME - 29 MINUTES
POURING TIME - 3 MINUTES
TOTAL AVERAGE TIME PER HEAT } 35 MINUTES

DETROIT ELECTRIC FURNACES SAVE PRECIOUS TIME IN THE MELTING OF FERROUS OR NON-FERROUS METAL

A foundry producing bronze valves and similar pressure fittings in a 1,000-pound Detroit Rocking Electric Furnace over a 5 year period averaged seventeen heats every 9 hours.

Yet this is by no means an unusual case. Performance records from all parts of the country reveal that Detroit Furnaces are doing an exceptional job of speeding up foundry production. Whether you pour ferrous or non-ferrous metals or alloys, you can speed up your operations, save labor and floor space, reduce metal losses and maintain precise metallurgical control by using the Detroit Rocking Electric Furnace. Write today for complete facts.

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 KUHLMAN ELECTRIC COMPANY • BAY CITY MICHIGAN



Small Ordnance Components, Iron Gears, Porous Bearings, Motor and Generator Brushes, Hard Carbide Tool Materials, Ore Briquettes

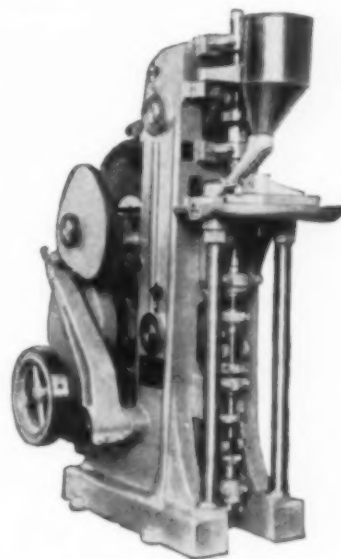
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For many years we have worked closely with engineers on research and development work in powder metallurgy . . . have developed automatic presses, standard and "special" models, with up to 8" die fill, to compress powdered metals into parts up to 4" dia., to form tablets or "cakes" up to 16" dia., to produce chemical catalysts at rates of thousands per minute.

We recently published a new 48-page illustrated catalog which shows hundreds of parts made by tabletting, more than 24 standard and "special" presses for powder metallurgy and other tabletting operations, contains specifications, information on selection and use of equipment and other engineering data.

Write for a copy of this catalog, No. 41-T. Or, if our engineering and laboratory facilities may help, we shall be glad to answer specific inquiries.



Model "S" Press, a general-purpose machine, applies 30 tons pressure. Output up to 35 pieces per minute.

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Representatives in New York, Chicago, Cincinnati, St. Louis, Cleveland, Detroit
Pacific Coast Representative: L. H. Butcher Company, Inc.



F. J. Stokes

**AUTOMATIC
TABLETTING EQUIPMENT**



EMBRITTLEMENT

(Continued from page 234)

(b) no embrittlement occurred in any alloy at any temperature with less than 15% Cr.

Other series tested the influence of titanium, columbium, silicon, manganese and carbon. None of these elements mitigated the trouble, except that 3% Mn

raised the lower limit of immunity to 17% Cr.

As indicated by BECKET, the brittleness can be removed by quickly cooling from above the embrittling range. The chromium alloys in this test, embrittled after 1000 hr. at 900° F., were reheated. At 1025° F. there was no change in 100 hr. At 1100° F. the alloy containing 28.7% Cr lost its brittleness in 5 hr., at 1200° F. in 2 hr., and at

1450° F. in 1 hr. These specimens could again be made brittle by heating at 900° F., clearly showing that the brittleness is a reversible phenomenon.

Standard German notched-bar tests were made at temperatures up to 1450° F. The impact value of 24% Cr-Fe at room temperature is always low, but when "tough" as shown by the bend test it rapidly rises with temperature of test from about 1.5 m.-kg. per sq.cm. at 70° F. to 21 at 300° F. and then remains fairly constant. The embrittled material (0.5 m.-kg. per sq.cm. at 70° F.) attains to 1.5 m.-kg. at 300° F. and rises slowly to 20 at 1450° F.

Acid resistance suffers by embrittlement; loss of weight in a solution of copper sulphate in dilute sulphuric acid is ten times as great. Inter-crystalline corrosion also occurs in chromium irons with 20 to 24% Cr. By special polishing technique the grain boundaries in the tough material appeared to be thicker—evidence of preferential precipitation in the brittle condition.

All these changes (or lack of changes in properties) are consistent with the suggestion that the embrittlement is caused by some form of precipitation. It is not due to any sort of carbide, since it is not affected either by carbon content or by the presence of strongly carbide-forming elements. It is dependent principally on chromium content, and hence on the precipitation of some iron-chromium compound. The only binary compound known is FeCr, the sigma phase, which, however, has not been detected in chromium steels with less than about 35% of chromium. This phase, moreover, is non-magnetic and its precipitation would involve a change in magnetic induction which was not found.

While the conditions for producing and for avoiding 900° brittleness are well established, much work remains to be done before a satisfactory explanation can be put forward.



**PORTER-LIPP
STRAIN GAGE**

**Accurate
Light
Compact
Prompt Delivery**

Rapid development of the volume and technique of structural testing in the United States during the past decade has given rise to the need for an all purpose strain gage. A mechanical type of gage that is accurate, yet inexpensive, light, compact, rugged and convenient is desirable in order to give consistent results in both the laboratory and the field.

The pressing demand for a satisfactory strain gage in the present time of emergency, during which European sources of instruments have been cut off, finds the Porter-Lipp strain gage filling a definite need for a superior instrument of this type.

The strain multiplication factor of this gage is approximately 300 and it has a range of 0.008 in. or better. Weighing only 0.4 oz. the Porter-Lipp has overall dimensions of 1 3/4 in. by 2 in. by 3/8 in. It is graduated so that each division corresponds to a strain of approximately 0.0001 in. and has a readable accuracy of 0.00002 in. for a gage length of one inch.

Write for our new bulletin No. 166

Baldwin Southwark



DIVISION OF THE BALDWIN LOCOMOTIVE WORKS
PHILADELPHIA

Furnaces for Defense

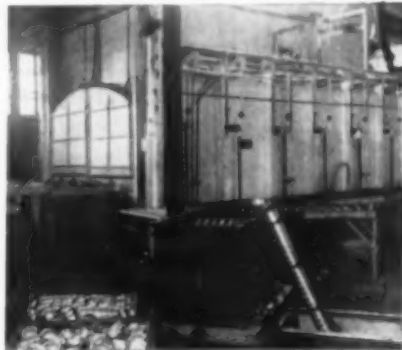
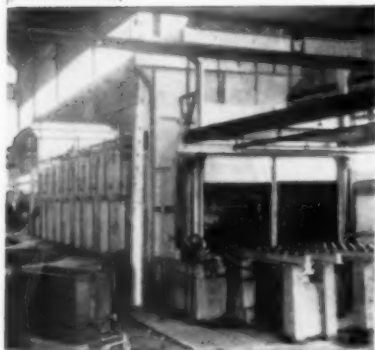
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CONTINENTAL'S trained engineers and extensive organization is devoted completely to Defense.

CONTINENTAL leads in Automatic Furnaces and automatic machinery for armament. Carburizing, nitriding, normalizing, hardening, bright annealing, and forging represents one important field of **CONTINENTAL** activities.

CONTINENTAL is serving in the field of steel heat treating, shell production, armor plate, tank parts and many others.

If you have a problem in annealing or heat treating armament, call on **CONTINENTAL**. Our extensive experience in armament work will be of great help to you on any Defense job.



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for
VICTORY**

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ENGINEERS, INC.**

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SCRAP COPPER

(Continued from page 226)

almost a quantitative replacement for nickel in the high strength machinable irons such as cylinder blocks. The Ford Motor Co. in particular makes considerable use of copper as an alloying element in cylinder irons and camshaft irons for its increase in the tensile strength.

Mr. JACKSON's figures on 1940 and 1941 consumption are as follows:

Estimated Copper Content in Iron and Steel Alloys

	1940	1941
Wrought steel		
Copper bearing steel	7,000,000 lb.	9,000,000 lb.
Low alloy, high strength	13,000,000	17,000,000
Cast iron	12,000,000	16,000,000
Malleable iron	1,200,000	1,800,000
Cast steel	3,000,000	4,800,000
Total copper	36,200,000 lb.	48,600,000 lb.

Of the 24,300 tons of copper so used in 1941, he estimates that 4430 tons was new copper or remelted copper ingot, that 3010 tons was in copper shot (a high iron alloy) and the balance from demolition copper and contained in the circulating load of iron and steel scrap used by the foundries and steel plants. Since this circulating load has been gradually increasing (no copper is lost on remelting) it now averages about 0.15% copper. The source of the copper used in 1941 is therefore something like this:

Ingot	4,430 tons
Shot	3,010
Demolition copper	10,580
Residual in iron and steel scrap	6,280
Total	24,300 tons

Unless restricted by official means the apparent consumption in 1941 of between 15,000 and 20,000 tons of copper may be expected to increase as long as scarcities in nickel, chromium and manganese exist. While the alloying action of copper is not nearly so well and widely known as these older elements, their very rarity as compared with the more generous supply of copper will cause steel makers and iron foundrymen to turn to it and expand its present substantial use. (About 4,000,000 tons of copper-bearing and copper-alloy irons and steels were made in 1941.) Use of copper steels will be greatly extended for welded gun mounts and for truck chassis, to mention only two important applications. In other words, the consumption of copper will grow in such proportions that it should be taken under control. The following means suggest themselves:

(a) Restrict the use of copper

(Continued on page 254)

The Only Flexible Salt Bath For NEUTRAL HARDENING OR CARBURIZING

that uses the
Same Materials in the Same Equipment!

AEROCASE* Case Hardening Compounds have been used successfully for many years to provide both *neutral* baths and *active* carburizing baths in the temperature range 1300° to 1650° F.

These materials can be used for either purpose by a simple adjustment in the amount of the activator which is added to the bath material, with the following results...

AS A NEUTRAL BATH... AEROCASE materials assure positive control and longer pot life than most other baths can be expected to provide.

AS A CARBURIZING MEDIUM... these same AEROCASE materials economically provide maximum rate of penetration and uniformity in hardness.

Wherever you may be seeking to improve results... neutral baths, carburizing baths, or baths for light cases... let AEROCASE Case Hardening Compounds show you the way to achieve positive control, greatest flexibility, with maximum economy in materials and equipment.

*Reg. U. S. Pat. Off.

AMERICAN CYANAMID

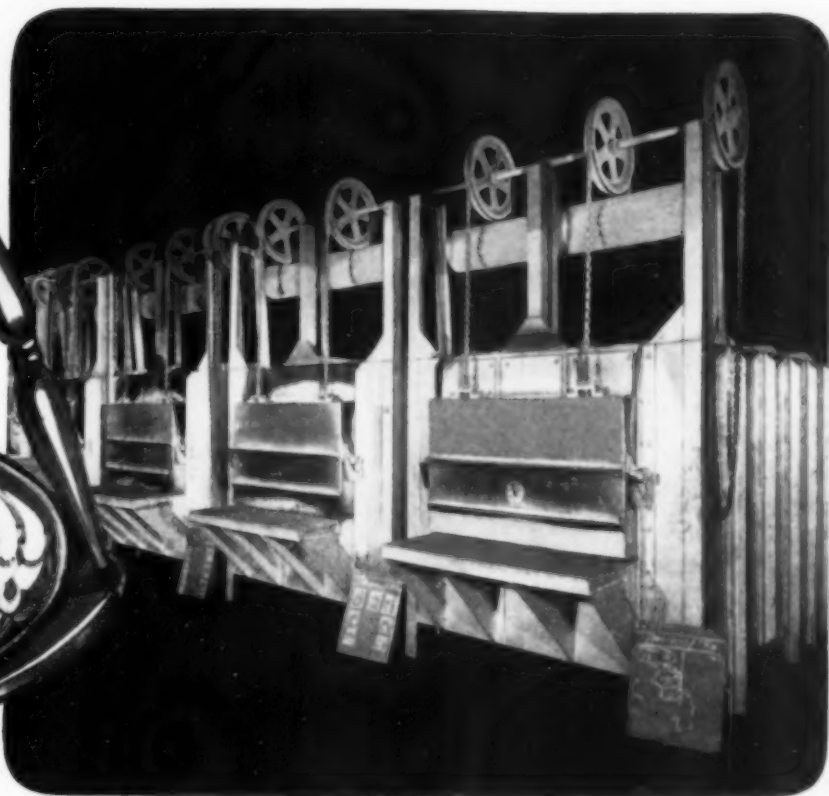


AND CHEMICAL CORPORATION

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Every PRODUCTION MINUTE *is precious*

You Can Get Early Delivery On A Standard S.F.E. Heat Treating Furnace

Never in our history has time been so vital, so valuable. War material must be produced and put into action, without a minute wasted.

Because the big bulk of this modern armament must be toughened by heat treatment, S.F.E.'s broad line of standard heat treating furnaces are playing a time-saving role in this important job.

The value of this variety of standard furnaces lies in the fact that fully 90 per cent of today's heat treating problems can be efficiently solved by a furnace built on a production basis and available at an early date on high priority orders. No waiting on design or engineering—S.F.E.'s standard furnaces are ready to go.

So—save those production minutes in heat treatment with an oil or gas fired furnace—up to 2500 deg. F. Let an S.F.E. furnace engineer recommend the installation your operation requires.

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of furnaces for heat treating, annealing, tool hardening, metal melting, salt drawing, carburizing, cyaniding and special designs either gas or oil fired.

Also fire clay, silica, silicon carbide, chrome and fused alumina oxide
Zero Refractories.

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FUEL ENGINEERING COMPANY

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SCRAP COPPER

(Starts on page 221)

metal or any of its alloys for the production of "copper bearing" steels (that is, steels containing less than 0.60% copper). The bulk of these steels contain 0.25% copper, of which four-fifths can be secured by proper selection of iron and steel scrap

(relatively high in residual or adventitious copper) and the rest secured from high copper pig iron. To secure a suitable supply of the latter it may be necessary to reopen some of the old mines in the Cornwall, Pa. region which produced pig iron containing up to 1% copper.

(b) In such "copper alloy" steels and irons (containing in excess of 0.60% copper) as permitted under preference orders,

copper shot should be used where and to the extent possible made from copper too high in iron to be usable by the non-ferrous foundry industry without resmelting.

This would prevent the use by iron and steel foundries of demolition copper which could readily be separated mechanically from its associated iron, and remelted into a copper alloy low in iron. To provide for this it is suggested that a group of competent representatives of the secondary copper industry and the iron and steel industry be asked to prepare specifications for ferro-copper shot, such that it could be produced in sufficient quantity from available copper, high in iron, and yet have no harmful amounts of other elements deleterious to the steel. A substantial portion of the tonnage could come from copper clad steel rod and wire, whose plant scrap runs about 70% iron, 30% copper.

A Strategic Alloy

(c) As to the future—although the main theme of this report has dealt with ways and means to conserve secondary copper—the fact must be faced squarely that the importation of chromium and manganese ores may be substantially reduced. Also the total availability of copper for use in the United States is greater than that of any other alloying metal in steel and cast iron. For example, the total availability of copper for all purposes will be some 20 times that of nickel.

It may be that the best war uses for copper will be its generous use in the production of alloy steels and cast irons. Its diversion to this purpose will naturally be determined as a compromise, taking into consideration the various "must uses" for copper, and its availability as compared with the availability of other steel or cast iron alloying elements.



On the alert . . .

In perfecting and offering "BERALOY 25" and other ternary BERYLLIUM-COPPER alloys, Wilbur B. Driver Company again evidences that it is "on the alert" to serve its country by furnishing special alloys* for vital war applications.

We have the facilities, personnel and experience to meet the most exacting specifications.

* Available in rod, wire, ribbon and strip both hot and cold rolled.



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NEWARK, NEW JERSEY



STRENGTH

HARDENABILITY

BORON

heightens the useful properties of Quenched Steels



Newly discovered possibilities of Boron as an alloying element are timely and important. Physical properties till now obtainable only with high percentages of strategic materials, can be satisfactorily produced with less of such materials, by the aid of Boron. Increased hardenability of heat-treated steels is one example. Other qualities of value are likewise obtained. The Molybdenum Corporation of America, producer of alloys and chemicals of Molybdenum, Tungsten, and Boron, invites correspondence. Write for specific information.



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STEEL PLATE PRODUCTION

IN RELEASING the June figure of 1,050,962 net tons of steel plate shipped from American mills to war industries, A. I. HENDERSON, director of materials for War Production Board, said:

"The nation owes a special debt of gratitude to the men who have made this record possible.

They have carried on a difficult assignment capably and willingly."

Approximately 75% of this record June output went to fill Army, Navy and Maritime Commission requirements. Even greater tonnage is expected after some new finishing equipment



KEEP IN STEP WITH OUR FIGHTING FORCES

• With an Army on the offense—all men and all units must advance according to plan. The same is true in the production of essential war machines and materiel. All steps must be synchronized for maximum output.

Alloy castings—whether pots, boxes, reverts,—muffles, tubes, rails, rolls, shafts,—can do their part for you in maintaining your production objective—if you can count on them for uniformly high heat-hour service.

MICHIANA has concentrated all effort for 24 years in the specialized field of heat- and corrosion-resistant alloy castings. MICHIANA Alloys have made performance records in a wide field of application. MICHIANA has the experience, the facilities, and skill to take care of your needs and help toward maintaining the quality and amount of your output.

MICHIANA PRODUCTS CORPORATION, Michigan City, Indiana

- Muffles
- Boxes
- Rails
- Rolls
- Retorts
- Pots
- Grids
- Tubes

MICHIANA
Heat-Resistant and
Corrosion-Resistant
ALLOY CASTINGS

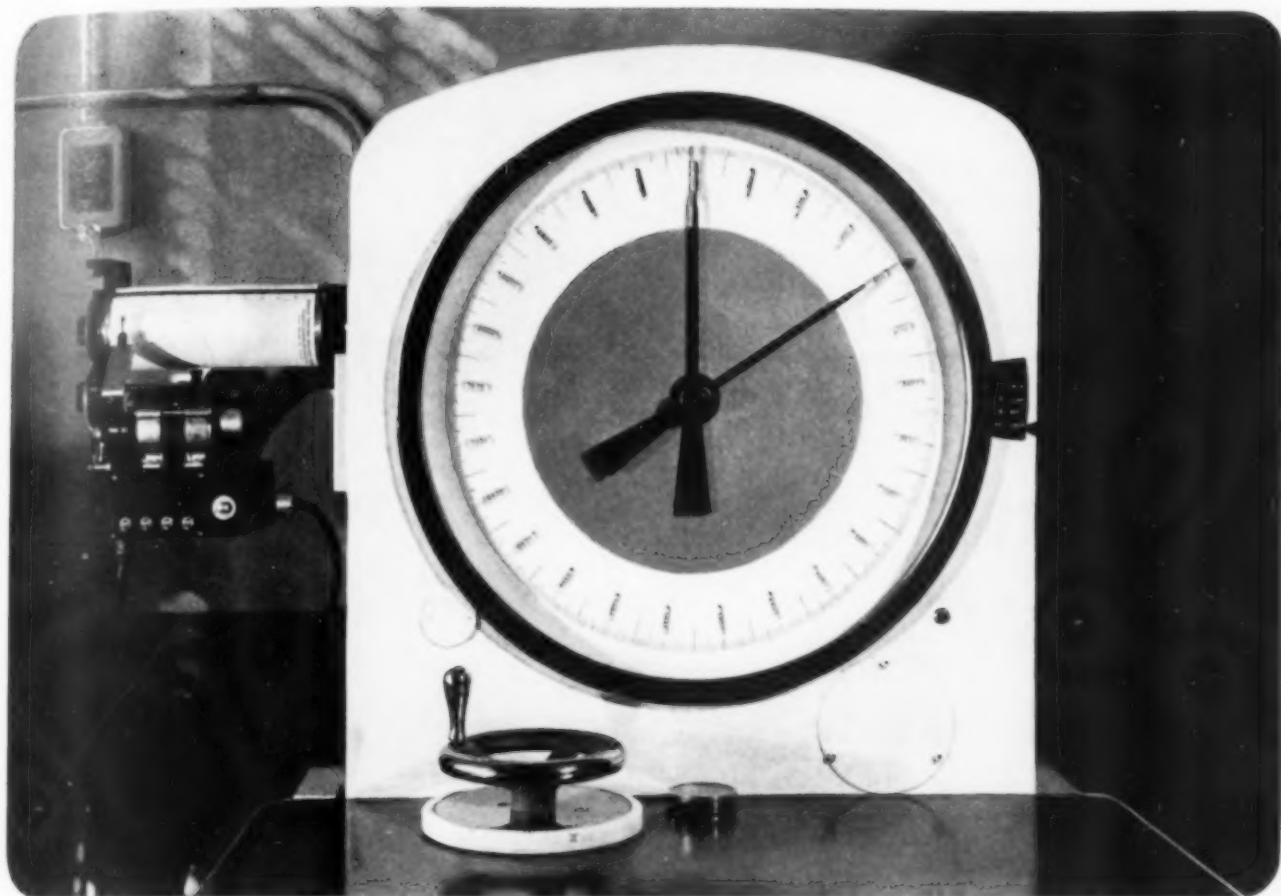
- Sprockets • Chains
- Heat-Resistant and
Corrosion-Resistant
Castings of All Kinds

can be installed. June is the second successive month plate output has topped a million tons and continues the steady increase started last fall. May shipments were 1,012,194 tons.

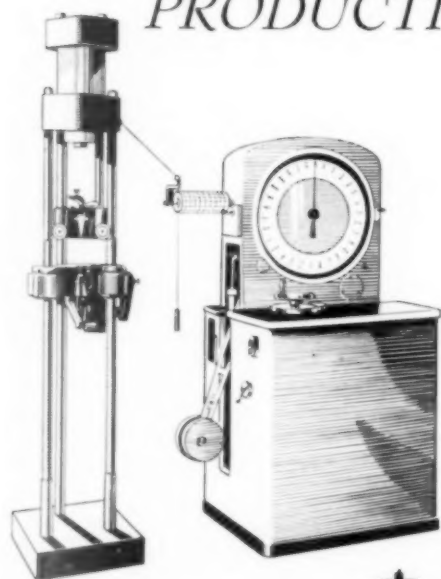
The greatest factor in the increase has been the conversion of continuous strip mills to plate production. Strip mills were designed to produce large quantities of steel sheet, mostly for the automotive industry. The problems involved in rolling and handling plate 0.5 to 1.0 in. thick as compared to sheets 0.04 in. thick are obvious. Heavier equipment is needed all along the line. Less obvious but actually more complex has been the problem of additional space to house this heavier equipment and to handle flat plate rather than coiled sheet-strip. Partitions have been ripped out, walls moved and every sort of expedient used to make way for the plates.

The most obvious additional requirement is for heavy shearing machinery, not only to cut the long pieces into car-load lengths but also to trim them to accurate width. The Irvin Works of Carnegie-Illinois, for instance, took a steam-driven shear of nineteenth century vintage, coupled it with an old roller-leveler and reconditioned both units into a modern electric-driven finishing line which now holds the record of 636.5 tons of plates in an eight-hour shift. As another instance, at the Campbell plant of Youngstown Sheet & Tube the hot plates are loaded directly on cars and sent six miles up the Mahoning valley to the Brier Hill World War I plant for finishing.

How successful this effort has been is evidenced by May output of 425,211 tons of plate from strip mills which were producing none a few months ago. June production of 489,704 tons, for the first time exceeded that from sheared plate mills. The latter, the regular source of plate, turned out 438,000 tons in June.



PRODUCTION TOOL... WORLD WAR II



TODAY, precision testing machines have become real production tools . . . tools that foretell success or failure for vital war materials.

Because the name RIEHLE stands for America's oldest manufacturers of testing machines, it has meant their logical acceptance from the first moment industry linked speed with accurate testing. Riehle Machines are making an important contribution in our present battle of production, proving repeatedly, in wartime as in peacetime, that . . . "ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS."

Model P-3 (illustrated at left) Universal type machine expressly designed to speed up routine tension testing of wire, strips, sheets and light bars. One hand wheel control. Five scale ranges. Open gripping heads at convenient height. Capacities up to 30,000 pounds.



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August, 1942; Page 257

INSPECTING ALUMINUM WELDS*

FUSION WELDS are inspected visually with or without low magnification for cracks, penetration, undercutting, size of reinforcement and flux removal. General remarks on inspection of copper welds in METAL PROGRESS, July issue, page 102, also apply to aluminum alloys.

Internal Inspection—X-ray examination of fusion welds may show porosity, lack of penetration, voids and other non-uniformity. Oxide films do not appear clearly, therefore X-ray examination should be coordinated with additional tests made by trepanned plugs or nick-break

tests on welded prolongs or cut-outs from the joints. Microscopic or visual examination of the weld structure on these specimens will show up oxide inclusions when they exist.

Mechanical Tests—In many applications, liquid or gas tightness of the joints is essential, and a proof test on the design assumptions is desirable. In such cases pneumatic pressure tests are applied where pressures up to 8 psi. will provide an adequate test on vessels smaller than 100 gal. Liquid tightness is established by immersing the part in water or painting the joints with a light oil or a soap suds mixture. For higher pressures and larger vessels use hydrostatic pressure rather than compressed gas, to avoid hazard if the tank fails.

In addition to pressure tests the tensile strength of reduced-section specimens, elongation, free-bend and nick-break tests are sometimes made on welded prolongs or cut-outs from the welds. Such tests are conducted only in special cases.

Repairs—Repairs to fusion welds, where cracks, undercutting and lack of penetration are concerned, should be made by chipping out the defective area and rewelding. Lack of sufficient reinforcement can be repaired merely by rewelding. Where low pressures are concerned small leaks are frequently stopped by peening, thus introducing no distortion, which may occur from making weld repairs.

If the welded casting is impregnated under pressure with sodium silicate or a phenolic resin, chipping and rewelding will merely extend the leaking area. Repair operations consequently are made by a sealing operation rather than a rewelding operation.

*From copyrighted pamphlet entitled "Tentative Recommended Practices for Inspection of Fusion Welding", prepared by a committee of the American Welding Society, April 1, 1942.

FOR TOOLS THAT MUST BE *TOUGH!*



USE JESSOP "RT" WATER-HARDENING TOOL STEEL

Jessop RT is a water-hardening tool steel of extreme toughness. It hardens to about C-62 Rockwell and when drawn back to about C-59 Rockwell, is unusually strong and tough. A tensile test, on properly treated RT, will show a breaking strength of 323,000 pounds per sq. in., with elongation in 2" of 4.5%.

In addition to this extreme toughness, you get all the hardness and wear resistance necessary, without danger of breakage.

There are a vast number of tools and parts—especially those classified as "battering tools"—that will perform with greater efficiency when made of Jessop RT Water-Hardening Tool Steel. Write for further information.

JESSOP STEEL COMPANY

WASHINGTON, PENNA., U. S. A.

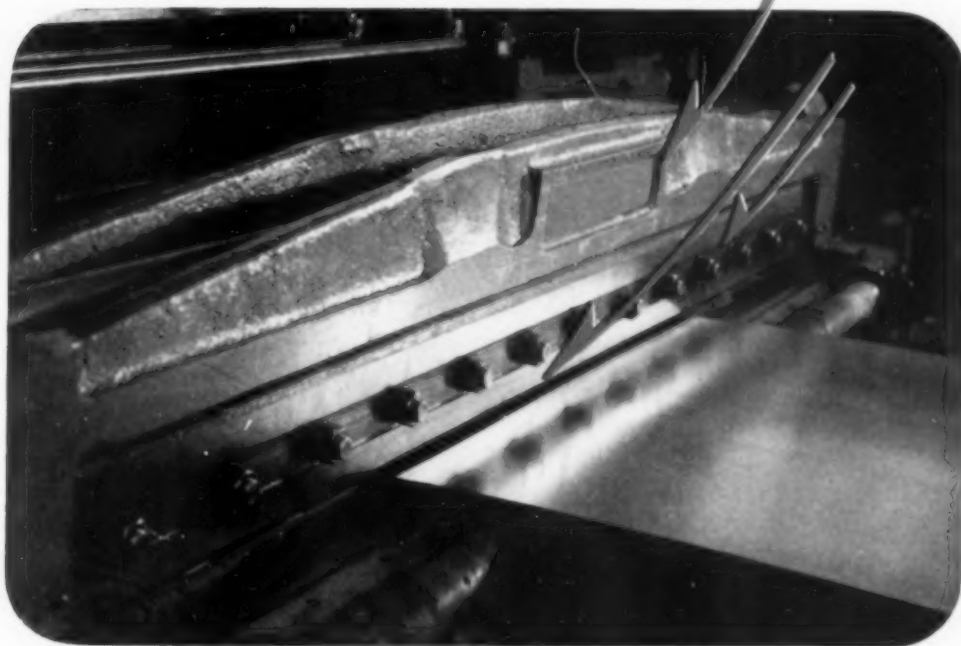


JESSOP STEELS FOR AMERICA AND HER ALLIES

CARBON • HIGH SPEED • SPECIAL ALLOY • STAINLESS • COMPOSITE STEELS

Save Time and Money

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with Heppenstall Shear Knives

Heppenstall Shear Knives require less grinding and deliver more cuts to the grind because they are made of special analysis alloy steel in Heppenstall's own electric induction furnaces according to methods developed through more than fifty years of quality shear knife manufacture.

Without any obligation, Heppenstall Engineering Service will gladly help you solve shear knife problems. And next time you order, specify Heppenstall. Use knives whose guaranteed high quality save you time and money. Write for full information, Heppenstall Company, Box M5, 4620 Hatfield Street, Pittsburgh, Pennsylvania.

Heppenstall

PITTSBURGH • BRIDGEPORT • DETROIT



Forging Fine Steels For More Than Fifty Years

August, 1942; Page 277

NEW PRODUCTS AVAILABLE

Electric Muffle Furnace

For economical and fast heat treating of small parts, drawing or tempering small lots, normalizing or annealing, pre-heating for subsequent high-speed hardening, and for emergency repair orders where one or two small parts must be heat treated in a short time. Developed by Cooley Electric Mfg. Corp., Indianapolis. Offered in two sizes — Type MH-3 has a chamber capacity 8 in. wide, 6 in. high by 14 in. deep; Type MH-4 is 10 in. wide by 6 in. high by 18 in. deep. Operating temperatures: 1750° F. continuously, 1850° intermittent. (No. 73)

Compressed Air Speeds Testing

Bomber part testing has been speeded 400% by Brewster Aeronautical Corp. engineers with a "Comparator" which operates in connection with a Rockwell hardness gage. It comprises a table-mounted yoke which supports a penetrator placed over an anvil. The die end of the penetrator is the same size as that used in the Rockwell hardness machine. Anvil moves upward against penetrator under compressed air at 100 psi. Piece being tested is thus pressed against the spherical



die sufficiently to indent its surface. Depth of the indentation is shown by a Starrett dial indicator which records any upward motion of the die. Foot controlled air valve allows the operator free use of both hands. A piece of correct hardness, as determined by the Rockwell machine, is used to calibrate the Comparator. Since every structural part of a bomber must be strength tested, Russell Gross of the Compressed Air Institute, East Orange, N. J., points out that the production time saved through the new device is tremendous. (No. 74)

Metal Refrigerator

Deepfreeze Santocel produces extreme low temperatures for chilling metal. Manufactured by Motor Products Corp., North Chicago, Ill. Offered in two tem-



perature ranges (from -40 to -50° F., and from -120° F. down). One of the numerous applications is for contraction of metal parts in compound fitting, to facilitate slide fits in assembly, relieve strain and possible fractures. Sub-zero tempering and stabilization of high speed tool-steel will also produce a combination of hardness, strength and ductility unobtainable by ordinary hardening or tempering. (No. 75)

Shell Case Furnace

Continuous conveyor furnace body for process annealing of brass and steel shell cases. Work is loaded into baskets and placed



on conveyor at entrance end. Furnaces are direct gas fired and use externally mounted recirculating air heaters. Despatch Oven Co., Minneapolis. (No. 76)

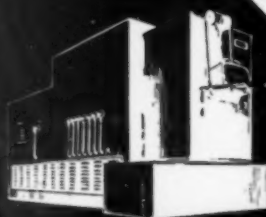
Comparator

Of high precision for convenient checking of large and small lots. Developed by the (Continued on page 280)

Readers may obtain complete details on these products by writing to the manufacturer direct, or to Metal Progress. We will gladly pass requests on to the manufacturer. Simply mention the paragraph numbers of the items in which you are interested.

LITHCO-LITHCARB

Achievements of Research



The Lithium organization's firm conviction nine years ago, that a chemically-neutral process embodying lithium, would offer inherent advantages in heat-treating and carburizing, became a realization as research progressed.

Industry consequently was offered a heat-treating process in which all steels, regardless of carbon or alloy analysis, could be hardened simultaneously with one atmosphere, without carburization or decarburization. Also, a process was made available for fast, bright gas-carburizing without scale, soot or coke, in which handling, sand-blasting, polishing, etc. operations were eliminated.

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THE LITHIUM CORPORATION

Raymond-Commerce Building, Newark, New Jersey

PRODUCTS

(Continued from page 278)

American Measuring Instruments Corp., New York City. Mounted on a base into which is built a ground and lapped table, a vertical micrometer adjustment quickly sets the comparator to zero position by means of a master gage. Instrument has a working capacity of pieces 12 in. high,

throat depth of 4 in., and a working circle, by swiveling the head, of 10 in. (No. 77)

Process of Joining Tips to Tool

An improved method of joining carbide and all other types of cutting tips and cutting blades to tool shanks, adapted both to small and large scale production, has been developed by Krembs & Co., Chicago, for use with furnace, torch or spot-welding meth-

ods. Process comprises a specially developed "Fluxined-Spelter" brushed on the contacting surfaces. Work is then assembled to tight fit and brazed. Finished braze looks like a gold-plated joint; there is no waste of joining material and practically no subsequent cleaning to do. (No. 78)

Temporary, Transparent Coating

Protective coating for metal is announced by Ault & Wiborg Corp., Cincinnati, known as Pro-tecktol. Material is completely transparent to permit visual inspection of coated parts, such as flat sheets, molds, irregular



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shapes, dies and bearings. One gallon, when sprayed to a thickness of one mil, will cover approximately 250 sq.ft. of surface, with a drying time at 200° F. of 6 to 8 min. Coating may later be peeled or blown off with an air jet, and reduced to liquid form for re-use. (No. 79)

New Stellite Steel Tool

Stellite 98M2 tools are made of a new cobalt-chromium-tungsten alloy especially designed to increase the speed of machining steel in production shops, according to Haynes Stellite Co., Kokomo, Ind. With the new tools, heavy roughing cuts may be taken on steel turning jobs with coarse feeds—and corresponding high rates of metal removal—yet tool life is long and economical because the new alloy is well balanced in red hardness, edge strength and toughness. (No. 80)

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ALLOY TOOL STEELS

STAINLESS STEELS

BEARING QUALITY STEELS

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WELD CRACKS

(Continued from page 212)

enable a ferrite-pearlite structure to be formed. There is little change in hardness but internal stresses are reduced and the limit of proportionality is lowered.

2. Heat base metal to about 750° F., weld, and allow joint to cool so that a considerable

amount of martensite is formed in the hot metal at and alongside the weld. Then raise to 1200 to 1400° F. to temper the martensite. The internal stresses will be reduced and the martensite will never be subjected to considerable contraction stresses.

3. When hardened plates have to be welded without tempering or softening the metal alongside the weld, the plates could be heated to 1475 to 1650°

F., cooled quickly to retain austenite at 850° F., welded while plates are held at 850 to 650° F., and cooled normally to room temperature, wherefore the plate and weld will be hard.

4. Preheat or post-heat the plates at a temperature near the A_r' critical temperature. The effects are: (a) Preheating the whole job reduces the relative movement of the two plates from the joint; local heating may cause a greater contraction across the joint. (b) The temperature gradient through the heat-disturbed zone in the base is less sharp, and internal stresses are possibly less irregular. (c) The slower rate of cooling of the joint influences the structure and certain properties of the martensite zone and also of the weld.

Cracking tests have been tried of various kinds. When hardened plates are welded a tempered zone occurs adjacent to the weld. Usually the cracking occurs in the weld throat or along the boundaries of the columnar weld crystals. Little is known about its fundamental cause, even in mild steel. The ratio of manganese to sulphur content, and the amount of oxygen in the steel are undoubtedly important. High alloy contents (such as 6% chromium) render the weld liable to cracking owing to the increased resistance to deformation, and the tendency to form columnar crystals. The propensity to cracking also varies among the high tensile electrodes.

Preheating of butt welds at 500 to 650° F. prevented cracking, although the average hardness of the heat-affected zone was only slightly decreased.

Shrinkage strains set up across a joint are due to: (a) Shrinkage of the weld metal, of the order of 1%. (b) The expansion of 0.5 to 0.9% when austenite changes to martensite in a rigid material. (c) Movement of the two plates due to thermal contraction and expansion. (Cont. on page 290)

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EXPERIENCE POINTS TO



WELD CRACKS

(Continued from page A-1)

Triaxial tension, even in small amount, superimposed on a uni-directional tension may change a ductile fracture to a brittle one.

Design—Welds should be widely spaced so that a large proportion of the contraction strain can be absorbed by elastic strain

or by controlled warping of the plates.

Welding Technique—Both weld and base cracking can be minimized by suitable electrodes. High tensile steel electrodes necessitate preheating. Water cooling of the plates may reduce the effects of thermal expansion and contraction and also tempering effects on hardened plates. Mild steel weld deposits are influenced by the "pick-up" of alloying ele-

ment from the base plates. The relative size of bead to plate thickness, speed of welding, size of electrodes are also important.

Modified composition of the steels used for particular applications may be the best solution. Another alternative may be the development of a steel having no critical ranges but capable of slow age hardening. A third method is to reduce the carbon to below 0.25% and obtain the required strength by an increased amount of alloying elements.

Base Metal Cracks

In the second part of the report on "Arc Welding of High Tensile Alloy Steels", welding tests were made on the two steels mentioned at the outset, using high tensile and special 18-8 austenitic steel electrodes. The austenitic steel electrodes had an extremely high resistance to hot cracking under restraint and the ability to withstand dilution from the plates without changing into a martensitic condition. A restrained butt weld type of test was chosen; it consisted of the plates to be welded, mounted on a heavy base plate, rigidly secured to the latter by several runs of mild steel weld metal along the outside edges. Asbestos paper separated weld pieces from backing, in order to prevent transfer of heat from one to the other. A single run weld was then made along the V groove from end to end of the test pieces.

The measurement of the temperature at which base metal cracks occur under these circumstances was made by extensometer readings of the movements of the plates immediately after welding, and it was found that cracking occurred within the range 100 to 200° F. (The martensite formation temperature measured by the dilatometer was 300 to 335° F., while a magnetic method later to be described gave 400 to 510° F.) These results

(Continued on page 292)

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WELD CRACKS

(Starts on page 212)

prove that cracking is not caused solely by the volume change associated with the formation of the martensite, and occurs at a lower temperature.

Preheating tests show that cracking can be prevented when the preheating temperature is

above 400° F., and tests carried out at lower temperature (300° F.) reveal some slight cracking. It might be assumed that "creep" of the hot metal was responsible for the integrity of the joint; however, increased creep is not essential to prevent cracking. It can be prevented equally well by controlling or delaying the cooling of the weld at low temperatures. The evidence suggests that the principal reason for non-

cracking in delayed cooling tests is that the martensite zone is tempered by an ultra-microscopic precipitation of carbides and that this leads to a toughening of the structure.

Microscopic examination confirms that small microscopic cracks are always present in the apparently sound metal in a specimen which has cracked under test. These cracks are transcrystalline, and appear to start from the material at the weld interface, running very close to that interface.

No cracks have been found in any test with the special 18-8 austenitic steel electrode. [The exact composition was not stated.] The most surprising fact, however, is the very large inward movement of the welding plates, showing that with these electrodes there is less "apparent creep" than usual. Microscopic evidence suggests that creep takes place in the thermally transformed zone before it has changed from austenite. The lower hardness of an austenitic weld agrees with the idea that austenite welds can creep more easily than high tensile welds at the lower temperatures. It is also known that the alloying elements diffuse through the interface, and (when austenitic electrodes are used) produce regions of permanently retained austenite (higher alloy regions) in the transformed martensite. It may be that these more ductile zones so toughen the martensite adjacent to the weld that it becomes capable of withstanding the stresses acting on it.

Curves drawn for the thermal gradients present at the end of creep and when the crack occurs indicate the average temperature of the plate at these two periods, so the contraction can be calculated and hence the theoretical crack width. Calculation indicates that cracking is caused by the combined action of the transverse stress and local stresses (i.e., a local tri-axial condition) and that the transverse stress

(Continued on page 296)



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WELD CRACKS

(Starts on page 212)

extends them and thus causes complete rupture.

Conclusions of this study are:

1. The cracking temperature is not identical with the temperature of the martensite formation, but lower, being just above room temperature.

2. All welds tested "creep" under the contraction stresses and this creep finishes at about 475° F. Preheating assists this creep effect, but the use of austenitic steel electrodes apparently results in much less creep than in usual welds.

3. Preheating reduces the cooling rate of the weld region, and tends to prevent cracking. Delaying the cooling, in this or any other manner, toughens the mar-

tensite without any loss in hardness and strength.

4. Failure is usually preceded by small cracks near the weld interface, and this region is most susceptible to cracking.

5. With austenitic steel electrodes cracking may be prevented by localized creep and stress relief at relatively low temperatures. The production of suitable austenitic material in the martensite adjacent to the weld may prevent cracking.

6. Poor root penetration of the weld metal may cause a notch effect likely to initiate a crack.

Toughened Martensite

Following these conclusions some tests were carried out to examine the view that delayed cooling has the effect of making steel more resistant to cracking by increasing its toughness. Notched specimens of the high Ni-Cr-Mo steel (0.32% carbon) were heated 5 min. at 1825° F., then cooled in a stream of air from a fan. Cooling was interrupted by immersing the specimen in an oil bath maintained at given temperatures. After the required time in the bath the specimen was quenched in cold water, and broke in slow bending.

Such delayed cooling increased the maximum bending stress by 6% to 15%, and accounted for an increase of about 22% in the "toughness" when the capacity for plastic deformation is also considered. (Plastic deformation amounted to only 2% of the total deformation in the case of the "normally cooled" specimen and to about 7% in the case of this specimen held at 480° F. for 35 min.) A definite improvement in toughness occurs with time in the constant temperature oil bath, but much of this improvement takes place in the first 10 min.

These results suggested a greater capacity for resisting the stresses of welding, and such steels were used in a series of

(Continued on page 300)

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WELD CRACKS

(Starts on page 212)

welding experiments. With a delay of 10 to 20 min. at 200° F. cracking was very slight. No cracks were found in a ½-in. steel plate used in both the hardened and the softened condition, when cooling was delayed for 10 min. at 300° F.

Magnetic Test

A magnetic method was developed to study the change to martensite adjacent to the weld, under actual welding conditions. Weld plates and metal are arranged in a magnetic circuit, and any change in their magnetic properties changes the flux in the circuit which can be measured by a search coil.

When using the apparatus, a

single run of weld metal was made, the electro-magnet switched on, and after 3 sec. had elapsed, the fluxmeter needle was released. Corrections were made for the tendency of the needle to creep back to the zero position.

Various electrodes were tried:

Austenitic Electrodes—The martensitic change is clearly marked between 470 and 340° F. Before the change point is reached the flux slowly increases as the temperature falls, due to (a) a slight change in the permeability of the weld metal or specimen with falling temperature, or (b) some structural change, hitherto unsuspected.

Mild Steel Electrodes—The flux before the martensite change occurs is reasonably constant, and no interface transformation occurs. The martensite transformation is at 430° F.

High Tensile Electrodes—The actual change in flux associated with the weld metal transformation is very small, but was noted at 860 to 960° F. The part of the specimen adjacent to the weld is austenitic and transforms at about 510° F. To overcome this effect the ends of the specimen were built up ½ in. with successive runs of high tensile weld metal, ground to shape, and the magnetic test performed as before. By this means the martensite change was entirely eliminated; the weld metal transformed, as before, at 930° F. ☉



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